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This manual was prepared by the staff of the
Entomology Division of the Naval Medical School
to serve as a laboratory guide for students, and as
a simplified ready reference for entomologists,
sanitation technicians, and medical officers.

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iii

TABLE OF CONTENTS

v

SECTION III. MOSQUITO SURVEY AND CONTROL

SECTION IV. ENTOMOLOGICAL TECHNICS

SECTION V. SUMMARIES

SECTION I
INTRODUCTION
THE IMPORTANCE AND PRINCIPLES OF SYSTEMATIC BIOLOGY

SECTION I

INTRODUCTION

THE IMPORTANCE AND PRINCIPLES OF SYSTEMATIC BIOLOGY

The identification and discrimination of various forms of life was the starting point of systematic biology. Aristotle (384-322 B.C.) suggested a classification of plants and animals, arranging all life according to higher and lower forms, and separating individuals by their own characteristics. This was accepted throughout the middle ages. About two hundred years ago an increase in the study of the various types of organisms emphasized the importance of adequate means of separating and naming species. This was aided tremendously by the Swedish Naturalist Carolus Linnaeus, who developed the binomial system of nomenclature wherein two Latin names were utilized for the identification of all living things; the first, to indicate a general group, the genus, the second, to designate a specific kind, the species.

With this method of binomial nomenclature he attempted to prepare a list containing the names of all known forms of plant and animal life. His Systema Naturae Regnum Animale classified all animals into groups, named them in accordance with his binomial system, and included short descriptions. Our present system of nomenclature dates back to his tenth edition of this publication released in 1758. All scientific names listed in this volume have been accepted, and all listed prior to its publication have been discarded.

The extreme importance of an adequate system of nomenclature becomes evident when it is realized that in the Phylum Arthropoda alone the estimated number of described species is well over 700,000, and that in the entire animal kingdom they number in the vicinity of 1,000,000. The great number of arthropods already described coupled with an increase of approximately six thousand each succeeding year, makes the mere naming and cataloging of the species a tremendous problem.

In the classification of living organisms it becomes evident immediately that the first logical division is the separation of plants from animals. These forms differ in cellular structure, movement, assimilation of food, and the possession of chlorophyll. Since arthropods are members of the animal kingdom, the discussion will be limited to this group. The animal kingdom is logically divided into a number of important groups called by the Latin name Phyla (singular Phylum) each having certain definite distinguishing characteristics. For example, the Phylum Chordata consists of animals which possess a notochord, a dorsal, tubular, nerve cord, and somewhere in the life cycle, paired gill slits (examples, mammals, birds, fish, and reptiles). Similarly, the Phylum Protozoa is made up of one-celled individuals or of colonies of similar cells that do not form tissue, and are usually microscopic. A group of such animals falling within a phylum would not all look alike, but certain ones would have

greater similarities than others. In the Phylum Chordata, dogs, cats, cows and horses have certain similarities in that they have four legs and hair on the body. They differ in many ways, however, the cow having horns and cloven hoofs and the dog foot pads and nails on the toes. Certainly they all differ markedly from chickens or birds, yet both groups are warm blooded, breathe with lungs, have vertebral columns, and four appendages.

These similarities and differences in animals have given rise to sub phyla, super classes or classes which further delineate the characteristics that place them grossly together. Man, horses, monkeys, whales and dogs are placed in the Class Mammalia because they are all warm-blooded, hairy, and suckle their young with mammary glands. They may be further separated into orders because of differences in reproduction, mode of life (aquatic or terrestrial), structure, and in many other ways. Man, apes, monkeys and lemurs have greater points of similarity and are placed in the Order Primates due to the fact that they possess four long limbs, each with five fingers or toes, bearing nails. The type of skeleton, size of the brain and its ability, facial features, location of the hair, and the development of hands and feet requires a further division into families. Thus, man belongs to the Family Hominidae, which separates him from the anthropoid apes, Family Pongidae. This family group is divided into two narrower divisions, the genus and the species. A family usually has several genera which are alike on the basis of certain structural characteristics, yet differ as to individual kinds. This requires the division of genera into species which normally interbreed, produce fertile offspring, and have constant characters. Species with slightly different forms, in various areas, are often assigned subspecies thus making the scientific name trinomial.

The existence of great numbers of animals and the interest in adequately describing them in different parts of the world has made international rules of scientific nomenclature mandatory. A permanent commission appointed by the International Congress of Zoology prepared our accepted International Rules of Zoological Nomenclature. This Commission also renders decisions in cases of error involving scientific names.

The rules of nomenclature include the following: The scientific names must be either Latin or Latinized (or considered as such if they are not of classic origin), and printed in italics; family names end in idae, and subfamily names end in inae, which is added to the stem of the name of the type genus; a generic name is a single word used as a substantive in the nominative singular, the first letter of which is capitalized; the specific name is usually a Latin adjective, and is written with a small initial letter; the person first publishing a scientific name with a description is the recognized author of the new species, and it is common practice to set aside a type specimen, designating where it may be found; the law of priority protects the initial author from an individual who might describe a genus or species a second time; the name of the author of a scientific name or an abbreviated name follows the genus or species without punctuation, example: Pulex irritans Linn.; when a species is transferred

2

from the original genus to another, the name of the original author of the specific name is retained, but placed in parenthesis. Example: <u>Sitotroga cerealella</u> (Oliver).

There are many forces which may cause a species to vary from the normal, such as environment (underfeeding, crowding, extremes of temperature) leading to the development of differences in color and other modifications that make identification more difficult for the systematist. There are other variations such as differences in antennal segmentation, for which the causes are unknown, and there may be mutations that change the form. The term "variety" has been used to delineate individuals of species which vary from the normal more or less consistently.

To illustrate the system of nomenclature three living organisms are classified below:

	<u>Man</u>	<u>Malarial Mosquito</u>	<u>Malarial Organism</u>
KINGDOM	Animal	Animal	Animal
PHYLUM	Chordata	Arthropoda	Protozoa
CLASS	Mammalia	Insecta	Sporozoa
ORDER	Primates	Diptera	Haemosporidia
FAMILY	Hominidae	Culicidae	Plasmodiidae
GENUS	<u>Homo</u>	<u>Anopheles</u>	<u>Plasmodium</u>
SPECIES	<u>sapiens</u>	<u>punctulatus</u>	<u>vivax</u>

CLASSIFICATION OF THE ANIMAL KINGDOM

<u>Phylum Protozoa</u>
Single celled animals, or cells in colonies, in which each cell performs all the necessary functions of life including reproduction.

<u>Phylum Porifera</u>
Sponges; primitive many celled organisms, motionless, attached to solid objects in water.

<u>Phylum Coelenterata</u>
Coelenterates; primitive animals believed to be the lowest forms that bear definite tissues. Includes corals, sea anemones, jellyfishes, and hydroids.

<u>Phylum Platyhelminthes</u>
Flatworms; bilaterally symmetrical worms which are normally flattened and have no true segmentation. They are considered to be the most primitive of the worms (planarians, flukes, tapeworms, and others).

Phylum Acanthocephala

Spiny headed worms; common parasites of all vertebrates, particularly fishes and birds. There are anterior rows of recurved spines for attachment to the host's intestinal wall.

Phylum Nemathelminthes

Roundworms or threadworms; elongate, cylindrical, more highly organized than the flatworms (nematodes, hookworms, filarial worms, guinea worm).

Phylum Bryozoa

Moss animals; found in colonies covering rocks and shells in sea water (moss like).

Phylum Ctenophora

Sea walnuts, comb jellies, jellyfish-like marine animals which swim by means of eight comb plates bearing paddles of fused cilia.

Phylum Gordiacea

"Horsehair snakes or hairworms"; long, slender, cylindrical worms found in water ponds, slow flowing streams, animal footprints, and other standing water.

Phylum Nemertinea

Ribbon worms; soft, more or less flattened, unsegmented marine or fresh water worms which live under stones, or burrow in the mud or sand.

Phylum Brachiopoda

Lamp shells; animals with bivalve shells resembling mollusks, but two halves are dorsoventral. Inhabit sea bottoms.

Phylum Echinodermata

Starfish, sand dollars, sea urchins, etc.; body usually with five radiating areas. Live on sea bottom beginning at tide line.

Phylum Mollusca

Slugs, snails, oysters, clams and others; soft, unsegmented body protected usually by a calcareous shell.

Phylum Annelida

Leeches, marine worms, earthworms; with typical elongated, segmented body. The segmentation resembles the Phylum Arthropoda, but they do not have jointed appendages.

PHYLUM ARTHROPODA

Insects, spiders, crustaceans, millipedes, centipedes and others; segmented, bilaterally symmetrical animals possessing a chitinous exoskeleton and jointed appendages.

Phylum Chordata

Tunicates, lancelets, and vertebrates; animals possessing the following at some stage of development: a notochord; a dorsal central nervous system; gill slits. This

PLATE I.

LIVING THINGS

PLANT KINGDOM

Forms not classified as animals or plants

ANIMAL KINGDOM

ULTRA MICROSCOPIC

Viruses

MICROSCOPIC

SCHIZOPHYTA

Bacteria

Rickettsiae

Spirochaetes

PROTOZOA

Trypanosome

MACROSCOPIC

THALLOPHYTA

Mushroom

BRYOPHYTA

Moss

PTERIDOPHYTA

Fern

SPERMATOPHYTA

Flowering plant

PORIFERA

Sponge

MOLLUSCA

Clam

COELENTERATA

Sea anemone

NEMATHELMINTHES

Threadworm

PLATYHELMINTHES

Flatworm

ECHINODERMATA

Starfish

ANNELIDA

Earthworm

ARTHROPODA

Tick

Housefly

Grasshopper

Spider

Flea

Mosquito

Tsetse fly

Louse

CHORDATA

Fish

Turtle

Snake

Bird

Lemming

Frog

Man

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5

phylum has representatives that are familiar to all. It contains both invertebrates and vertebrates. Among the invertebrates are the tunicates and the lancelets. The vertebrates include the following:

Class	Pisces	Fishes
Class	Amphibia	Salamanders, frogs, toads
Class	Reptilia	Lizards, alligators, snakes, turtles
Class	Aves	Birds, domestic fowl
Class	Mammalia	Bats, whales, cats, horses, man

Biologists recognize 4 or 5 phyla of plants and 12 to 20 phyla of animals. Plate 1 illustrates some of these and serves as a guide in orienting the taxonomic position of the Phylum Arthropoda.

PHYLUM ARTHROPODA

Place in the Animal Kingdom

About eighty per cent of the animal species described belong to the Phylum Arthropoda. As stated previously the Annelida resemble the arthropods in possessing segmented bodies. There is a further resemblance in the structure of the nervous system which has a dorsal pair of ganglia connected with a ventral nerve cord. The resemblance ceases here, the appendages are simple and unsegmented, the coelom is large and there is no specialization in various areas of the body. The structure of the nervous system and heart of certain primitive crustaceans resemble the annelids and the segmental nephridia of certain worm-like Onychophora are somewhat similar to the annelids. There are many fossil records of winged insects dating back to the Upper Carboniferous era over two hundred million years ago, but the origin of arthropods cannot be determined by fossil evidence. Based on morphological and embryological evidence, the insects probably originated from an arthropod similar to the Symphyla. This is a class that includes the garden centipedes which resemble primitive, wingless insects by their single paired antennae, head structure, and styli on the abdomen. It has been pretty well established through morphological studies that the first insects were wingless and similar to the silverfish and Japyx.

General Characteristics

An arthropod is a segmented, bilaterally symmetrical animal possessing a hard exoskeleton and jointed appendages. All of these diagnostic characters are seen in the centipede figured below. (Fig. 1).

6
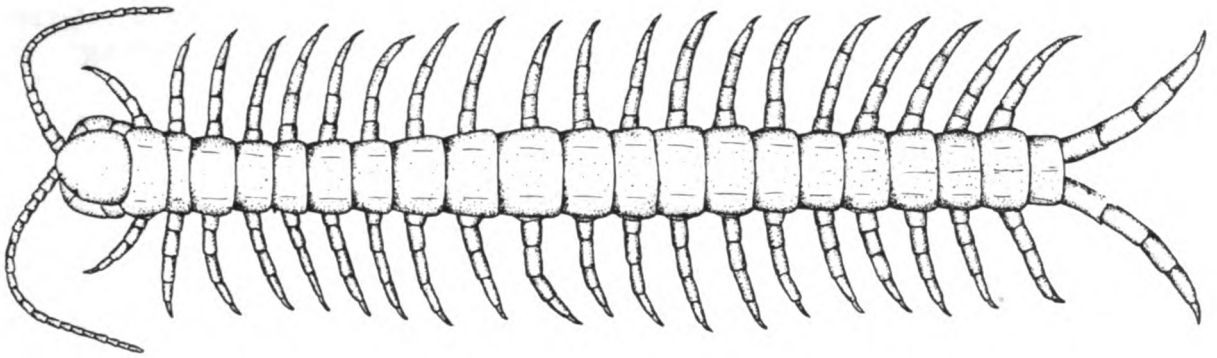
Figure 1
A centipede, showing its body segments, bilateral symmetry,
hard exoskeleton, and paired, jointed appendages.

The segments into which an arthropod's body is divided are grouped character-
istically in the various classes. The centipede illustrates a generalized arthorpod in
which only the segments of the head have been so fused as to obscure the external
evidence of segmentation.

Symmetry may be defined as the balanced orientation of body parts. In the great
majority of animals, two general types are common -- radial and bilateral.

Animals which possess radial symmetry have their body parts arranged radially
around a central axis like the parts of a cylinder or spindle. Any radial cut through
this central axis will divide the animal into identical halves. Sessile animals or those
which move about infrequently usually show this type of symmetry. (Fig. 2A).

Animals with bilateral symmetry have their body parts arranged equally on the
right and left sides of a dorso-ventral plane running the length of the body; and it is
only along this one plane that a cut will divide the body into two equal parts, each of
these parts being a mirror-image of its mate.

All arthropods are bilaterally symmetrical, but this is not an exclusive diagnos-
tic feature, since almost all freely moving animals possess this type of symmetry.
(Fig. 2B.)

Figure 2.

A. Sea anemone, a radially
   symmetrical animal.
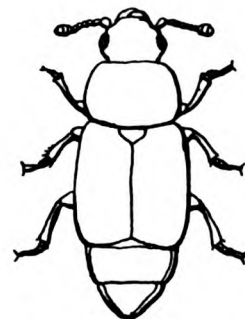
B. Beetle, a bilaterally
   symmetrical animal

7

The supporting framework of an arthropod's body is on the outside and is referred to as an exoskeleton. In higher animals, such as the vertebrates, the supporting framework is internal and is referred to as an endoskeleton. (Figure 3.)
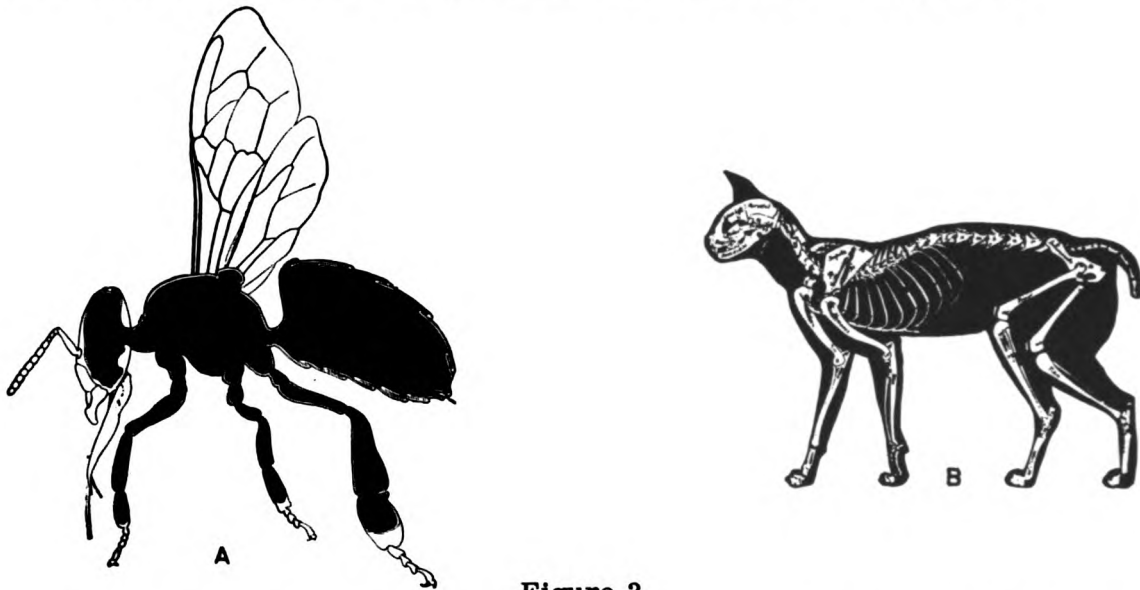
Figure 3.

A. Exoskeleton of an arthropod.   B. Endoskeleton of a mammal

An arthropod's body is thus covered with an inexpansible shell. In order to make any considerable increase in size, this shell must be discarded and a new and larger one formed. All arthropods throw off this exoskeleton at various times during their lives, a process which is known as molting. Before the old shell or cuticula is split off, a new soft shell is secreted inside of it by the underlying layer of epidermal cells. Some of these same cells then secrete a "molting-fluid" which is poured out between the old and the new shells, loosening one from the other. The old cuticula is then split open by pressure from within and the arthropod squirms and crawls out of it, pulling its appendages free. The arthropod is now in a "soft shell" condition. In certain of the crabs, the shell remains soft for several days, during which time they are considered a delicacy because the entire claw, for example, can be eaten rather than just the inner muscles.

There is considerable expansion in the size of the arthropod while it is in the soft shell condition. This is accomplished by absorption of large quantities of water into the tissues, or by the inflation of the alimentary canal with air. Thus, when the outer portion of the cuticula begins to harden or "set," and hard, armor-like plates are formed over most of the body wall, the new shell is of sufficient size to provide space for additional growth.

The cuticula is continuous and uninterrupted from one hard plate to another, but remains soft and flexible between the plates to permit body movement. (Fig. 4.) The cuticula also extends as a thin lining over the fore-and hind-gut, but not the mid-gut.

8
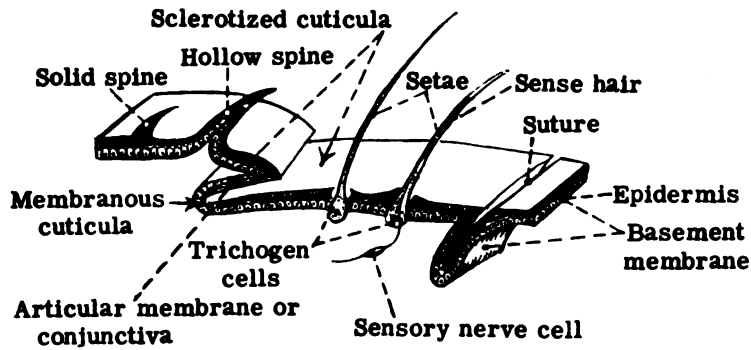
Figure 4.
Section of the body wall of an arthropod

In some arthropods, growth and molting cease when the adult stage is reached (as in insects), while in others growth and molting continue periodically throughout adult life (as in lobsters and crabs).

The period of time between each immature molt is called a stadium. The arthropod, itself, during any stadium is referred to as an instar. Thus a first-instar arthropod is one that has hatched from the egg, but has not yet cast its first skin. The time from hatching to the first molting is the first stadium.

The paired appendages of an arthropod are characteristically jointed, being made up of a number of rigid pieces which articulate with each other at connecting joints. The configuration of the joint determines the type of movement possible. Some permit movement in only one axis, as in the elbow joint of man. Others permit movement in several axes, similar to the shoulder joint of man. The jointed appendages of an arthropod are adapted for many functions, such as locomotion, feeding, reception of sensation, and assisting in the reproductive process. Regardless of the function of the appendage, the jointed condition is readily visible. (Fig. 5.)
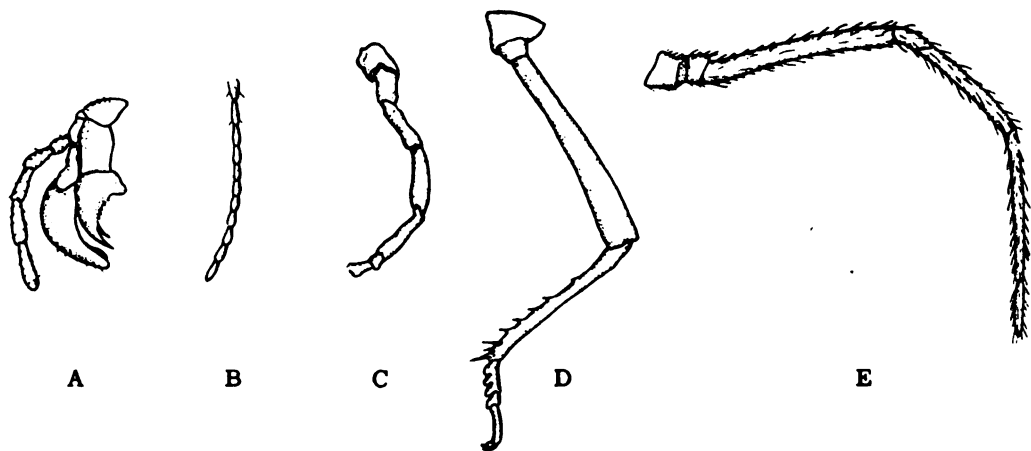
Figure 5.
Jointed appendages. A. Insect maxilla. B. Antenna. C. Leg of a tick. D. Leg of an insect. E. Leg of a spider.

9

PLATE II.

TYPES OF ARTHROPODS TRANSMITTING HUMAN DISEASES

CONENOSE BUGS
transmit
Chagas' Disease

FLEAS
transmit
Plague
Endemic Typhus
Dog Tapeworm

LICE
transmit
Relapsing Fever
Epidemic Typhus Fever
Trench Fever
cause: Vagabond's disease

"SOFT" TICKS
transmit
Relapsing Fever
cause: Tick paralysis

"HARD" TICKS
transmit
Tick-Borne Rickettsioses
(Rocky Mt. Spotted Fever)
(Brazilian Spotted Fever)
(Fievre Boutonneuse)
(So. African Tick Fever)
("Q" Fever)
Tularemia
Colorado Tick Fever
Bullis Fever
cause: Tick paralysis

MITES
transmit
Tsutsugamushi
(Scrub Typhus)
cause: Dermatitis

NON-BITING FLIES
transmit
Yaws
Typhoid Fever
Dysenteries
Cholera
Conjunctivitis
cause: (larvae) Myiases

BITING FLIES
transmit
Tularemia
Sand-fly Fever
Filariases (Loaiasis, Onchocerciasis)
African Sleeping Sickness
Leishmaniases (Kala-azar, Oriental Sore)
Bartonellosis
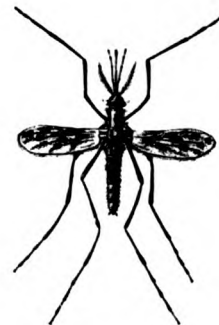
MOSQUITOES
transmit
Malaria
Yellow Fever
Dengue
Filariasis (Elephantiasis)
Encephalitis

10

The arrangement of certain of the <u>internal organ systems</u> (Fig. 6) of arthropods is also characteristic of the phylum and helps to define the group. The <u>nervous system</u> consists of a <u>dorsal brain</u> connected to a ventral nerve cord by circumesophageal connectives. The <u>digestive system</u> consists of a tube running the entire length of the body, having an entrance or <u>mouth</u> and an exit or <u>anus</u>. The <u>circulatory system</u> is <u>dorsal</u>.
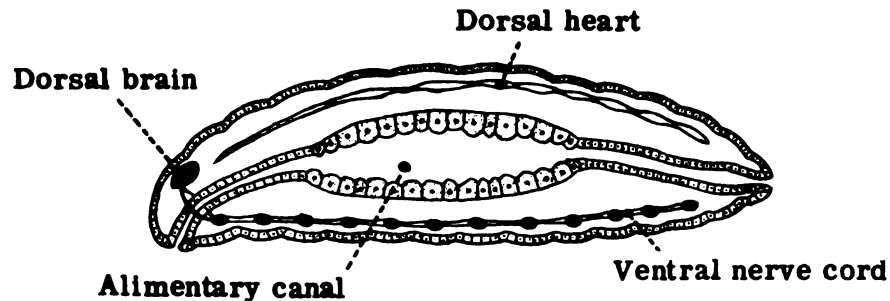
Figure 6.
Diagram of the internal organ systems of an arthropod.

<u>Importance of Arthropods to Health</u>

Arthropods affect the health of man and other animals in two ways: (1) by pathological conditions directly attributed to them; (2) by conditions caused by pathogenic organisms for which they act as essential vectors, or accidental carriers. (Plate II.)

Among pathological conditions caused by Arthropods are the following:
   (1) Dermatosis (skin disorders)
   (2) Myiasis (infection by fly maggots)
   (3) Injury to eyes, ears, and nostrils (irritation caused by arthropod bodies and secretions)
   (4) Venoms (stings, bites, nettling hairs)
   (5) Allergies (wing scales, cast skins, and pulverized bodies)
   (6) Nervous disorders

Pathological conditions attributed to pathogenic organisms may be the result of rickettsiae, viruses, protozoa, spirochetes, bacteria, yeasts, and fungi. These conditions involve the fields of pathology, immunology, entomology, mycology, protozoology, and bacteriology.

The medical entomologist must combine his knowledge of the arthropods with the biology of pathogenic organisms, in order to understand the mechanism by which the arthropod acquires the pathogen, harbors it, becomes infectious, and eventually transmits the organism.

11

Vectors of Disease

Arthropods transmit agents of disease in two ways: (a) Mechanical transmission; (b) biological transmission. In the former case, they act as passive carriers of pathogenic agents such as bacteria, viruses, and protozoa. In the latter instance, they act as essential hosts of pathogenic agents and, in addition to transporting them, serve as hosts for their development, cyclic changes, and multiplication.

(a) Mechanical transmission: Bacteria, protozoa, and the eggs of helminths may be transported mechanically in many ways. They may adhere to the hairy legs, wings, and mouth parts or gain entrance to the arthropod's body, ultimately coming to rest in the alimentary canal, body cavity, salivary glands, and muscles. They may transmit the infection by deposition of pathogens in such susceptible places as the lips, eyes, ears and wounds (example pink eye) or following bites by contaminated mouth parts (example yaws). The pathogens may be regurgitated into the blood stream when a blood sucking arthropod feeds. Similarly, simple inoculation during subsequent feedings may be effected by piercing, sucking mouth parts which have been contaminated with blood pathogens (house flies and anthrax). Organisms may be discharged with the feces and ultimately rubbed into abraded skin (Chagas' disease), be deposited on the skin when the vector is crushed (Rocky Mountain spotted fever), or they may gain entrance when the arthropod is swallowed. In addition, arthropods may breed or feed in excrement, become contaminated and ultimately transfer their burden to vegetables, meat or water. The agents of cholera, amoebiasis, and typhoid may be transmitted in this manner.

It has been shown that fly maggots feeding upon excrement may ingest bacteria and pass them in the viable state to the adults through their pupae. Adult flesh flies have been known to become infective with anthrax in this manner.

(b) Biological transmission: This type of transmission may be divided into three types. (1) Propagative; (2) cyclo-propagative; and (3) cyclo-developmental.

(1) Propagative: The organisms undergo no cyclical changes, but multiply as in culture tubes. The plague bacillis, Pasturella pestis, will serve as an example since it multiplies in the stomach of the flea and infection takes place when the entrance to the stomach is blocked, and the flea regurgitates bacteria laden blood into the wound. Other examples of the propagative type are tularemia, typhus, spotted fever, yellow fever, and dengue.

(2) Cyclo-propagative: The organisms undergo cyclic changes and multiply in the process. For example, the malaria parasites undergo their sexual cycle in the female mosquito. Flagellation of the male gametocyte takes place, male gametes are formed and a corresponding change takes place in the female gametocytes (maturation). Conjugation takes place, sporozoites are ultimately formed, find their way to the salivary glands and are infective when introduced into the mammalian blood by the mosquito. The organisms of trypanosomiasis and leishmaniasis are also cyclopropagative.

(3) Cyclo-developmental: The organisms undergo developmental changes but do not multiply. In filariasis the microfilaria is imbibed by the mosquito with the

12

blood of an infected individual. The microfilaria loses its saclike sheath, burrows through the wall of the insect's stomach, through the thoracic muscles, molts twice and migrates to the head region where it may be ejected through the medium of the proboscis when the insect bites.

Arthropods may burrow into the skin, or live in the intestine or nasal sinuses. In scabies, the mite Sarcoptes scabiei var. hominis (Hering) burrows into the skin releasing toxic substances which cause intense itching. Another form of invasion is known as myiasis, which involves an infestation of tissues and organs by the maggots of flies. This may occur when fly eggs or larvae are accidentally ingested with con-taminated food or water, causing accidental intestinal myiasis. The invasion of skin wounds by fly larvae often causes dermal myiasis and the adults are often attracted by odors from nasal discharges, wounds, ulcers or sexual organs for oviposition in such areas, from whence the larvae gain entrance to the body.

Arthropod venoms

The venoms of arthropods are normally utilized for defense or in killing or paraly-zing their prey. In general, the higher animals are only attacked when the arthropod is disturbed. This is especially true of the stinging or biting arthropods possessing venom glands, such as scorpions, spiders, centipedes, certain ants, bees and wasps.

The irritating effects of the bites of some of the blood sucking arthropods, are due to salivary gland secretions which act as irritants, contain neurotoxins which may cause paralysis; hemolysins, or blood anticoagulins. Again, if the mouth parts are contaminated with pathogenic organisms, painful infections may result.

Certain larvae of the Lepidoptera (moths and butterflies) have body hairs which irritate and inflame the human skin upon contact. There are also species of Coleop-tera (beetles) the body fluids of which blister the human skin following contact. Insects having nettling hairs and blistering body fluids are called urticating insects.

The hairs or spines on caterpillars that have urticating properties are hollow and contain venom supplied from venom cells. They are pointed and barbed permitting easy penetration and dissemination of the venom, but in the case of coarse spines, the venom may only spread over the skin causing a rash. The venom apparatus may con-sist of a primitive, single seta supplied with a venom gland cell, or several modified hairs may be inserted in a large venom gland cell which produces a true venom that fills the hairs. In the case of large, hollow spines, the tips of the spines penetrate the skin, break off, and thus inject some of the venom.

The urticating or vesicating beetles have a blistering substance free in the body fluids. In the case of the family Meloidae it is called cantharidin. Dermatitis is pro-duced when the beetles are crushed releasing the body fluids on the skin, or when they are handled. Another family, the Staphylinidae, also has a genus with many species that produce blisters on contact with the human skin.

13

The stinging insects have highly specialized venom apparatuses which are very effective. Many individuals suffer severe reactions from insect stings and sometimes die within an hour. In some of the Hymenoptera a specialized organ, the sting, may penetrate the skin to a depth of one-tenth of an inch. The sting is connected to a system of glands which secrete the venom. The venom of some Hymenoptera may be deadly to certain insects and small animals, or it may have only a paralyzing effect. Some use the sting to immobilize other insects which are used as food for their young.

Arthropods as pests

Many arthropods are merely annoying by reason of their presence. They often have distasteful odors as exemplified by cockroaches and bedbugs. Certain insects such as stinkbugs impart unpleasant tastes to berries and fruits. They may become alarming to the individual by crawling over the body as do lice and bedbugs; small insects may enter the eyes. Insects destroy enormous quantities of edible products, damage buildings and other structures. Certainly they lower human morale and efficiency, and may cause a major reduction in effective man hours.

Control of arthropods

The control of arthropod pests and disease vectors should have high priority for the purpose of maintaining morale and efficiency, combating disease, and preventing property loss. Such diseases as malaria, typhus, dengue, encephalitis, filariasis, Rocky Mountain spotted fever, tularemia, and dysentery are examples of diseases that can become very destructive to human life if left uncontrolled. The control of arthropods has become so extensive that it would be impossible to adequately treat the subject in a laboratory guide of this nature. Chapters 9, 10 and 11 of the Manual of Naval Preventive Medicine give current information regarding vector control, insecticides, dispersal methods, and the proper handling of Navy Standard insecticides. For this reason, control measures have been largely eliminated from this guide with exception of field malaria control which involves surveys, water level management, and other mechanical measures of value to preventive medicine units in the field.

There is another facet of control that deserves attention, called natural, or biological control. Parasites of man, domestic animals, and plants have been accidentally spread to various countries with their hosts. Some, like the Argentine ant, European cornborer, and codling moth; fleas, bedbugs, and lice, have become established. Some are now nuisances, others are important from the standpoint of crop loss. Insects have been purposely brought to this country to combat or destroy harmful arthropods. The control of the cottony-cushion scale of citrus trees by a beetle imported from Australia is an example of a successful introduction. It is true that the balance of natural populations is maintained by parasitism, predatorism, and disease, but in general the practice of transplanting alien arthropods is dangerous, since those that are harmless in their native environment may become greater pests than the animal they were introduced to combat.

14

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PLATE III.

CLASSES OF ARTHROPODS

Millipede

CLASS DIPLOPODA

Centipede

CLASS CHILOPODA
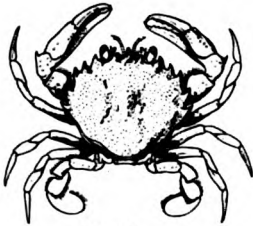
Crab
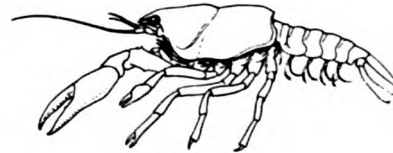
Crayfish

CLASS CRUSTACEA

Spider
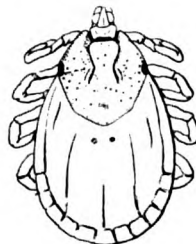
Tick

Scorpion

CLASS ARACHNIDA

Butterfly

Wasp

Beetle

CLASS INSECTA   NAVAL MEDICAL SCHOOL '44

16

SECTION II

THE CLASSES OF MEDICALLY IMPORTANT ARTHROPODS

SECTION II

THE CLASSES OF MEDICALLY IMPORTANT ARTHROPODS

The division of the Phylum Arthropoda into classes is based on the grouping of
the segments into body regions, and on the number and arrangement of the locomotor
appendages.

The various classes are graphically represented on Plate III with the exception of
the Class Pentastomida (Fig. 7), and it is possible to assign a medically important
arthropod to its proper class simply by comparing the specimen with the illustrations.
Usually, illustrations are not available for use in the identification of arthropods, espe-
cially when smaller categories (such as orders, families, genera, and species) are
being considered. In the absence of illustrations, biologists use descriptive keys to
aid in identification. To illustrate the foregoing, a simple descriptive key to the clas-
es of arthropods of medical importance is given below. Opposing descriptive state-
ments are arranged in couplets. The features of the specimen under consideration
will agree with one (and only one) of the statements. At the end of the statement will
be found the name of the Class to which the specimen belongs, or the number of an-
other couplet from which a further choice of statements must be made. Each state-
ment of a couplet must indicate a category of classification (in this case a CLASS) or
another couplet for subsequent choice.

Key to the Classes of Arthropods of Medical Importance

1. Body worm-like 2
   Body not worm-like, divided into definite body regions 3

2. Without legs in adult stage, two pairs of ventral hooks near
   mouth, body ringed but not segmented; two pairs of short legs
   in larval stage; endoparasitic .... PENTASTOMIDA
   With many, paired, jointed legs 4

3. Five or more pairs of jointed legs; two pairs of antennae;
   aquatic or semi-aquatic .... CRUSTACEA
   Three or four pairs of jointed legs 5

4. Each body segment with one pair of legs ...... CHILOPODA
   Each body segment with two pairs of legs ...... DIPLOPODA

5. Three pairs of jointed legs in adult stage; body composed of
   head, thorax and abdomen; winged or wingless; one pair of
   antennae .... INSECTA
   Four pairs of legs in adult stage; body composed of cephalothorax
   (head and thorax fused) and abdomen, or fused into sac-like form;
   wingless; no antennae .... ARACHNIDA

17

CLASS PENTASTOMIDA
(tongue worms)

General Characteristics

Pentastomids are endoparasites of vertebrates, inhabiting the mouth, esophagus, or respiratory organs. They are elongate, flattened or cylindrical animals with external rings that do not correspond to internal segmentation. The adults have no external appendages other than two pairs of hollow, retractible hooks near the mouth associated with large secretory glands. Separation of the body into definite regions, as in insects, does not occur. In fact, there is little resemblance to arthropods except in the mite-like form of the larva. The internal organs consist of a simple nervous system, a rather straight digestive system, and reproductive organs, but there are no circulatory or respiratory organs. The males are somewhat smaller than the females.

Geographical Distribution

Armillifer (porocephalus) armillatus (Wyman)-Africa, A. moniliformis Diesing-China, Java, Manila and Sumatra, Linguatula serrata Frölich-Africa, Germany, Switzerland, Panama, Brazil, Chile, U.S. (Texas), Pentastoma najae-India.

Life Cycle and Habits

The eggs are laid in the posterior portions of the nasal passages of vertebrates and are released from the body in nasal secretions. The eggs embryonate upon reaching damp vegetation or water and when swallowed by herbivorous mammals, hatch in the digestive tract. The young larvae penetrate the intestinal wall, migrate to the liver, spleen, lymph nodes or lungs where they become encapsulated in the tissues of the host. In this capsule they develop for about six months before transforming to the nymphal stage. The nymphs are released from the tissues by digestive action after their host is ingested by another animal. They ultimately migrate to the nasal passages where they transform to adults. The intermediate hosts are rabbits, goats, sheep, snakes and occasionally man. The definitive host of L. serrata is normally the dog.

Relation to Man

Armillifer armillatus, A. moniliformis and Pentastoma najae have been taken either in the larval or nymphal stages from man, probably acquired from eating raw snakes. Linguatula serrata (Fig. 7) has been found more frequently than the others in man, probably obtained from eating uncooked or poorly cooked rabbits, sheep or goats. In the majority of human cases there are no symptoms. Occasionally, in multiple infections, there is abdominal pain and jaundice, and rarely an inflammation of the

intestinal wall or liver. Heavy larval infections experimentally have proven injurious or even fatal. The diagnosis is normally post mortem, so the majority of the cases are autopsy findings. There is no known reliable treatment. Control lies in the avoidance of raw flesh, polluted water and raw vegetation in infested areas.

Figure 7.
Nymph of <u>Linguatula</u> <u>serrata</u> (Tongue Worm)
(Redrawn from Faust, 1927)

CLASS CHILOPODA

(centipedes)

General Characteristics

Centipedes are elongate, segmented, dorso-ventrally flattened, worm-like, terrestrial animals with many jointed legs. The body is made up of a distinct head, and fifteen to over 170 segments, each bearing one pair of tracheal openings, and one pair of seven-jointed appendages (Fig. 1). Large species range up to ten inches in length. The head bears a pair of extremely long, many jointed antennae, a pair of strong mandibles, and two pairs of maxillae. The first body segment bears a pair of modified legs just ventral and lateral to the mouth, which form claws, the terminal joints of which are curved, sharply pointed, horny fangs connected with venom glands (Fig. 8). Each fang has a slit-like opening just below the tip for the emission of venom.

Internally, centipedes have a straight digestive tract, salivary glands, and resemble the insects in having posterior Malpighian tubules for excretion, and a heart that extends the length of the body.

Geographical Distribution

Centipedes are found mostly in tropical, subtropical, and temperate regions of the world.

Life Cycle and Habits

In the centipedes the sexes are distinct, and the females either oviposit or are viviparous. The young resemble the adults, having approximately the same number of segments. They hide by day under stones, rubbish, leaves, logs and in other dark areas, feeding by night on earthworms, insects, mice or lizards, depending upon their size. The prey is quickly killed or paralyzed by venom and is masticated for ingestion by means of mandibles. The secretion injected is thought to be primarily a digestive enzyme, containing only a small proportion of venom.

Relation to Man

Most centipedes are harmless, since only a small number have fangs strong enough to penetrate the human skin. They only bite large animals when handled or threatened in some manner, and then only in self defense. The amount of venom introduced depends somewhat on the size of the centipede and the time that has elapsed since the fangs were previously used. The small, fast running, house centipede Scutigera cleoptrata (Linn.), with 15 pairs of long spindly legs has been known to pierce the skin and cause severe pain. Large American species Scolopendra heros

20

Gerard and <u>S</u>. <u>morsitans</u> Linn. ranging from four to six inches in length, inflict painful bites. The ten inch <u>S</u>. <u>gigantea</u> Linn. of the tropics is considered to be very poisonous, sometimes requiring short hospitalization.
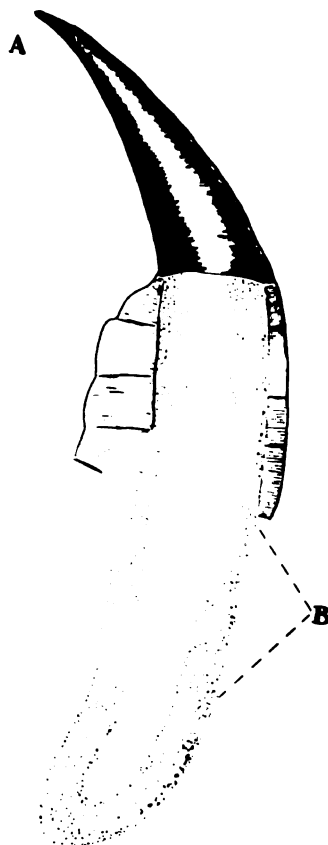
Figure 8.
Poison fang and gland of <u>Scolopendra</u> <u>heros</u>, a centipede.
(A) fang. (B) venom gland. Redrawn from Baerg, 1924.

Centipede bites may cause local pain, erythema, hardening of the skin, formation of papules, rash, swelling, purple patches, and swollen axillary glands, but such symptoms usually subside within 24 hours if the wound is uninfected. There have been no deaths recorded from the bites.

Treatment usually consists of locally applied palliatives such as weak ammonia, compresses of sodium bicarbonate or epsom salts.

No control measures other than avoidance are usually necessary.

Some Centipedes of Public Health Importance (Courtesy Department of Health, Education, and Welfare, Public Health Service, Communicable Disease Center, Atlanta, Ga.)

SCIENTIFIC NAME	PUBLIC HEALTH IMPORTANCE	DISTRIBUTION
Chetechelyne spp.	intestinal infestation	Central Europe, North Africa
Geophilus spp.	nasal, intestinal and urinary infestation	Europe, North Africa
Himanterium spp.	intestinal infestation	Central Europe, North Africa Madagascar
Lithobius spp.	intestinal and nasal infestation	South United States, Europe, North Africa
Scolopendra cingulata	venomous; household pest	South Europe, North Africa
Scolopendra heros	venomous; household pest	South United States
Scolopendra morsitans	venomous; household pest	Southwest United States
Scolopendra polymorpha	venomous; household pest	Southwest United States, Mexico
Scutigera spp.	intestinal infestation; common household pests, particularly Scutigera cleopatra, the eastern house centipede	Cosmopolitan
Stigmatogaster spp.	intestinal infestation	South and Central Europe

CLASS DIPLOPODA
(millipedes)

General Characteristics

The members of this class are characterized by their long, cylindrical bodies of many segments with two pairs of legs and two spiracles for each of the greater number of body segments. Some are brightly colored whereas others are jet black (Plate III).

Geographical Distribution

Millipedes of medical importance are found in tropical, subtropical, and temperate areas of the world.

Life Cycle and Habits

Millipedes prefer a dark, moist, terrestrial habitat such as is found under rotting

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logs, leaves, or beneath stones. On certain of the tropical Pacific islands milli-
pedes have been observed crawling on low-lying bushes.

Reproduction is by internal fertilization. The male is provided with modified
appendages, termed the gonopods, which are attached to the seventh segment. The
females have a single gonad with a duct opening on the third segment. Each egg is
covered at the time of oviposition with a layer of regurgitated food. At the time of
hatching the young have only six segments and three pairs of legs, additional ones be-
ing added in front of the anal segment with successive molts.

Relation to Man

Millipedes may serve as facultative or accidental parasites of man, and as the
intermediate host for Hymenolepis diminuta (Rudolphi). However, they are primar-
ily of medical importance because of their repugnatorial or "stink" glands which are
present in the majority of non-pselaphognath members. Some of the tropical species,
particularly those of the Order Juliformia, and members of the genera Julus, Spiro-
bolus, Rhinocrichus and Spirostreptus have been known to squirt their repugnatorial
fluid for several inches. One investigator found Rhinocrichus latespargor Loomis of
Haiti could shoot its fluid a distance of 33 inches. This fluid has been known to cause
permanent blindness in chickens and small mammals. In humans it may produce a
vesicular contact dermatitis.

Millipedes were said to be a continual source of annoyance during the invasion of
some of the Western Caroline Islands when the troops, in crawling over the ground,
came in contact with the repugnatorial fluid of these pests.

No control is considered necessary for millipedes.

Some Millipedes of Public Health Importance (Courtesy Dept. Health, Education,
and Welfare, Public Health Service, Communicable Disease Center, Atlanta, Ga.)

SCIENTIFIC NAME	PUBLIC HEALTH IMPORTANCE	DISTRIBUTION
Fontanaria virginiensis	rare vector of rat tape-worm	United States
Julus spp.	vesicating exudate; intestino-urinary infestation	
Orthoporus spp.	vesicating exudate	Mexico
Polydesmus spp.	intestino-urinary infestation	
Rhinocrichus latesporgor	vesicating exudate	West Indies
Rhinocrichus lethifer	vesicating exudate	West Indies
Spirobolus spp.	vesicating exudate	
Spirostreptus spp.	vesicating exudate	

CLASS CRUSTACEA
(crabs, lobsters, crayfish, copepods, sowbugs)

General Characteristics

Crustaceans are mainly aquatic, normally breathing by gills. They possess two pairs of antennae and at least five pairs of legs. There are many forms, the larger ones, such as crabs, crayfish or lobsters have calcareous exoskeletons, the smaller are more delicate in structure.

The copepods are elongated, segmented forms with reduced numbers of body segments and appendages. The body is composed of a cephalothorax and abdomen. There are six pairs of biramous (two branched) appendages on the head and five pairs of biramous swimming appendages on the anterior thoracic trunk region. The abdomen is tail-like, four or five segmented, and without appendages.

Geographical Distribution

Some species inhabit fresh and salt water throughout the world including lakes, ponds, wells, and pools.

Cyclops bearing guinea worms occur in North Africa (Nile Valley), Iran, India, Pakistan, Afghanistan, Russian Turkestan, Arabia, the Guianas, Brazil and the Caribbean Islands. The guinea worm may be present in fur-bearing animals (dogs, mink, foxes, raccoons) in the United States.

Cyclops bearing Diphyllobothrium species (tapeworms) have been reported from Indo-China, China, Japan, Formosa, Korea, Africa, Australia, Sumatra, Java, Holland, British Guiana and the Unites States, with scattered reports of cases in man from almost all parts of the world.

Crustaceans harboring Diphyllobothrium latum (Linn) are found in the lake districts of the world. The parasite has been recorded from Italy, Switzerland, France, Bavaria, Rumania, Manchuria, Japan, Palestine, Africa, the United States, Canada, South America, Finland, Baltic States, Russia and Siberia.

Crustaceans containing Paragonimus westermani (Kerbert) (Oriental lung fluke) are found in India, the Far East, particularly Korea, South Japan, Formosa, Philippines, China, South America, and Africa; in the lower animals it is possibly cosmopolitan in its distribution.

Life Cycle and Habits

There are thousands of species of crustaceans varying greatly in color, structure, life cycles, and habits. The majority are predacious (sowbugs are land forms that are vegetarians) feeding on small aquatic animals. Those that dwell on the bottom

24

in the water, obtain their food from debris, while coconuts serve as food for some land crabs. The eggs of crustaceans are usually carried outside the body in sacs, although a few are carried similarly but internally. A few of the crustaceans are parthenogenetic. The eggs are very resistant to drying and can withstand desiccation for at least two years, being sometimes transported by the winds.

Large crustaceans such as the crayfish live on lake and stream bottoms hiding among rocks and in burrows. Food consists of living and dead aquatic life, although some are vegetarians. The eggs remain suspended from the female, hatching in about five weeks. The young resemble the adults, having a gradual metamorphosis similar to that of certain insects. Several months are required for the development of the immature forms to the adult stage.

Copepods that serve as the intermediate hosts of parasites are found only in fresh water. Their eggs are carried in sacs extending outward on either side of the female abdomen (Fig. 9). The larvae, after emerging from the eggs, undergo three stages of development before becoming adults, which permits the addition of segments and appendages.
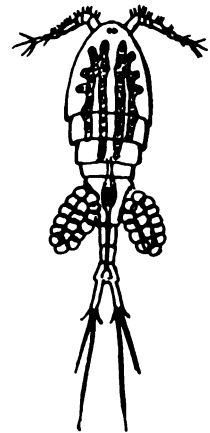
Figure 9
Cyclops

Relation to Man

Dracunculus medinensis (Linn.), the guinea worm, lives as an adult in the subcutaneous tissues of man. The female produces first stage larvae in small surface ulcers usually in the skin on the lower extremities or back of the victim. The ulcers burst upon contact with water, freeing the larvae which are ingested by Cyclops. They bore through the stomach wall of the crustacean, enter the hemocoel where they molt, become infective, and remain viable for months. Man becomes infected by drinking water containing the infected Cyclops. The larvae migrate through the intestinal wall, and develop to maturity in the body tissues. Dogs, horses, cattle and other animals serve also as hosts and aid in the spread of the disease.

The lesions cause intense itching. There is vomiting, nausea, diarrhea, and severe dyspnea presumably due to the toxic secretions. There are no symptoms until the females are mature and the lesions appear.

Diphyllobothrium species, causing sparganosis in man, have Cyclops as their first intermediate hosts. The procercoid larvae may next infect tadpoles, becoming plerocercoids when these amphibians are ingested by frogs, reptiles or mammals. Man may become infected by ingesting infected Cyclops, by eating infected animals, or by using infected animal flesh as poultices over the eyes or other sensitive portions of the body. When ingested, the plerocercoid larvae penetrate the intestinal

25

wall and migrate through the subcutaneous tissues and muscles. In man, the larval worm is usually referred to as Sparganum mansoni.

Diphyllobothrium latum, the broad fish tapeworm, is carried in one larval stage by Diaptomus and Cyclops. Minnows ingest these copepods, and are in turn eaten by larger fish. Man becomes infected upon eating uncooked or dried fish containing the larval tapeworm.

Paragonimus westermani, the human lung fluke, may be harbored by the larger crustaceans such as crayfish and fresh water crabs. The eggs commonly occur in the sputum or feces of man. From four to six weeks after they reach water, the miracidium escapes from the egg shell and penetrates a snail within 24 hours. The miracidium in the snail gives rise to a sporocyst, which in turn develops into rediae and daughter rediae, finally giving rise to cercariae. These escape from the snail and may enter fresh-water crabs or crayfish and encyst as metacercariae. Consumption of raw or smoked crabs or crayfish transmits the flukes to man or other animals.

Preventive measures against the above parasites would appear to be centered in the proper disposal of sewage to prevent contamination of water with the ova of Diphyllobothrium, and Paragonimus; in refraining from eating smoked or dried fresh-water fish or crustaceans containing the other parasites; and in the use of chemicals to treat well-water against the cyclops laden with guinea worms.

CLASS ARACHNIDA
(spiders, scorpions, mites, ticks)

General Characteristics

The arachnids are air-breathing arthropods in which at least the first two body regions (head and thorax) are fused to form a cephalothorax. There are four pairs of legs in the adult and no antennae.

Relation to Man

Two orders of arachnids, the Araneae (spiders) and the Scorpionida (scorpions) are of some importance because of their venomous bites or stings. The third order, the Acarina, includes the mites and ticks. These are of far greater importance because they are concerned in the transmission of such serious diseases as Rocky Mountain spotted fever and tsutsugamushi. All three orders are discussed more fully below.

Key to the Orders of Arachnids of Medical Importance

1. Body divided into two regions, cephalothorax and abdomen   2
   Body with one region, formed by fusion of head, thorax and
   abdomen .... ACARINA

2. Abdomen jointed to cephalothorax by a narrow pedicel.
Segmentation absent or indistinct .... ARANEAE

Abdomen broadly joined to cephalothorax. Body distinctly
segmented .... SCORPIONIDA

ORDER SCORPIONIDA
(scorpions)

General Characteristics

Scorpions (Plate IV) are arachnids characterized by the possession of a pair of stout appendages bearing pincer-like claws (pedipalps) situated just in front of the four pairs of walking legs; the cephalothorax is unsegmented and covered by a dorsal plate, the carapace, which contains two to twelve eyes and the abdomen has twelve segments with the terminal group of five much narrowed and tipped by a ventrally curved venom spine attached to a pair of glands in the last segment (Fig. 10). The venom is ejected through two pores located near the tip of the spine. The adults have a pair of combs on the ventral side of the second abdominal segment. Their respiratory organs are four pairs of book lungs located ventrally between the third and the sixth abdominal segments.

Geographical Distribution

Scorpions inhabit the Southern United States, and the subtropical and tropical regions of the world.

Life Cycle and Habits

Many species live from three to five years. Mating is preceded by a courtship dance and often followed by the female eating the male. Several months later the female gives birth to living young. Shortly after birth the young climb onto the mother's back and cling there by means of their pincers until after their second molt.

Scorpions hide by day under stones, loose bark, debris, among books, in shoes, dark closets and in folded bed covers or towels.   They are often found in children's sand boxes and can remain buried in loose gravel for six months without food or water. At night they forage for food using the comb-like pectins and their large pedipalps in the search, carrying the abdomen arched over the back. Their food consists of spiders, small scorpions, or large insects which they sting into insensibility, hold with their mouth pincers (chelicerae) and crush between the coxal segments of the pedipalps before devouring.

Over six hundred species have been described, fifty in the United States.

PLATE IV

PRINCIPAL CHARACTERS FOR IDENTIFYING ORDERS OF ARACHNIDS OF MEDICAL IMPORTANCE

BODY COMPOSED OF
CEPHALOTHORAX AND
SEGMENTED ABDOMEN
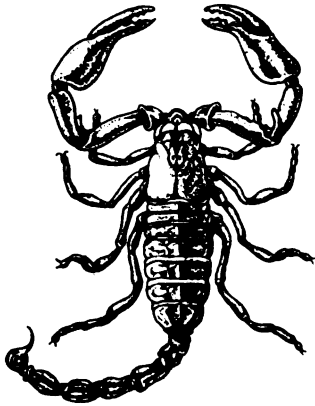
BODY COMPOSED OF
CEPHALOTHORAX AND
UNSEGMENTED ABDOMEN,
CONNECTED BY A SLENDER
PEDICLE
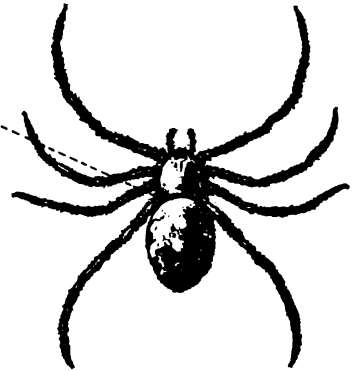
Scorpionida
(Scorpions)

Araneida
(Spiders)

HEAD, THORAX, ABDOMEN FUSED
FORMING AN UNSEGMENTED
SAC-LIKE BODY

Acarina

(Mite)

(Tick)

28
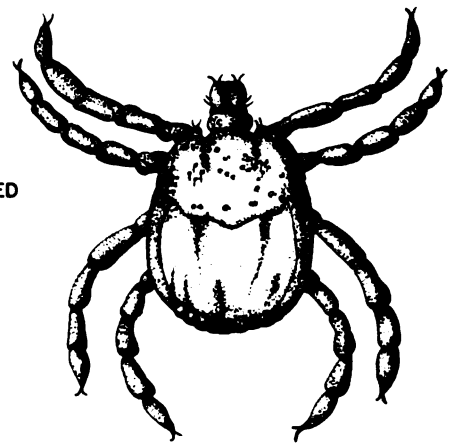
Whip scorpions (Order Pedipalpi) resemble scorpions, but do not have venom glands or spines.

Relation to Man

Scorpions invade homes during the rainy season in the tropics and may be found on dirt floors, in books, shoes, towels, clothing or near drinking water containers where man may touch or step on them. Their poison consists largely of a neurotoxin, which may cause death, although a less dangerous haemotoxic fraction is also present. It has been estimated that 25 per cent of the scorpion stings in school age children in the British West Indies and 60 per cent of those in Egypt are fatal. In the United States (Southern Arizona) the dangerous scorpions are either straw, lemon yellow, or greenish yellow in color, while the less poisonous species are gray, brown or black.

Physicians have the problem of distinguishing scorpion stings from spider bites as well as bee and wasp stings, tick paralysis, and other entities with which they might be confused.

Scorpion stings have a single penetration point which is inflamed, frequently hardened and accompanied by lymphadenitis medial to the point of entrance; with radiating throbbing, aching pain and ascending motor paralysis. There may be numbness, twitching of extremities, excess salivation, thirst, sweating, speech impairment, difficulty in swallowing, vomiting, and convulsions. The temperature may be elevated to 104° F. or slightly more. The patient may die of respiratory paralysis within two hours in extreme cases.

The following first aid treatment has been recommended for scorpion stings (Stahnke 1953):
1. Immediately place a tight tourniquet between the sting area and the body, as near the injury as possible.* Make no incisions.
2. Hold a piece of ice on the injury while a pan of crushed ice and water is prepared.
3. Immerse the injured member in ice water, well beyond the tourniquet.
4. After five minutes of immersion, remove the tourniquet, continuing the immersion of the injured part for at least two hours in ice water. The patient must be kept warm in order to maintain good circulation.

Figure 10.
Spine and glands of Centruroides vittatus, a scorpion. (A) Pore in spine; (B) Gland. Redrawn from Baerg.

*There are areas of disagreement regarding the use of tourniquets since serious consequences may result from improper application.

Stahnke indicates that if the venom was administered by one of the two lethal scorpions of Arizona, no serious effects will be experienced after this amount of immersion. For the Gila monster, six to seven hours are required, and rattle snakes or other pit vipers may require six to twenty hours of treatment depending on the size of the snake.

If the body is stung in an area where immersion in ice water is not possible, a large pack of finely divided ice may be used, or ethyl chloride if care is taken not to freeze the tissue (spray only to point of frost formation; after frost disappears, the spray should be repeated). When the area is properly chilled an ice pack will serve.

Antivenins have been prepared against the stings of some of the more dangerous scorpions. Prevention of stings lies in avoiding the hiding places of scorpions, or approaching them with care. The use of an emulsion of benzene hexachloride at the rate of 500 mgms. per square meter inside homes and on the premises of several thousand families in Brazil, during a three year period, decreased scorpion accidents substantially. In scorpion infested areas, individuals should carry ethyl chloride "bombs" for use in cooling down the area around a scorpion sting, thus slowing down the absorption and circulation of venom until medical attention can be obtained.

Some Dangerous Neurotoxic Scorpions (Courtesy Department of Health, Education, and Welfare, Public Health Service, Communicable Disease Center, Atlanta, Ga.)

SCIENTIFIC NAME	DISTRIBUTION	COMMENTS
Buthus quinquestriatus	Near East, North Africa	Egyptian scorpion; mortality to 50% in children
Centruroides sculpturatus	Southwest U. S., Mexico	Deadly sculptured scorpion
Centruroides gertschi	Southwest U. S., Mexico	Gertsch's scorpion
Centruroides suffusus	Mexico to Panama	Durango scorpion; mortality 50 cases/year in Mexico
Euscorpius italicus	South Europe, North Africa	
Prionurus australis	North Africa	
Scorpio maurus	North Africa	
Tityus trinitalis	Trinidad	Mortality 4.7% (689 cases)
Tityus bahiensis	Brazil	
Tityus serrulatus	Brazil	Mortality 11.0% (1328 cases)
Tamulus spp.	India	
Buthus martenis	Manchuria	"Rarely fatal"

Key to Some Common Scorpions of the United States

1. Sternum 5-sided 2

   Sternum 3-sided (family Buthidae) 5

2. Basal membrane of last tarsal segment with 1 spur,
   at least on some legs 3

   Basal membrane of last tarsal segment with 2 spurs,
   at least on some legs 4

3. Spine or tubercle under the stinger absent (family Scorpionidae).
   Southern Florida, Panama, West Indies
   Ophisthacanthus leptura .... Thin-Tailed Scorpion

   Spine or tubercle under the stinger present (family Diplocentridae) 14

4. Two ocelli on each side of carapace (family Chactidae).
   Southern California, Mexico. Broteas alleni .... Allen's Scorpion

   Three to 5 ocelli on each side of carapace (family Vejovidae) 15

5. First tarsal segment of fourth legs with a distal spur.
   Texas, California, Mexico
   Uroplectes mexicanus .... Pale Mexican Scorpion

   First tarsal segment of fourth legs without a distal spur 6

6. Oblique rows of teeth on fingers of pincers flanked with
   supernumerary rows of teeth (Centruroides) 8

   Oblique rows of teeth on fingers of pincers not flanked with
   supernumerary rows of teeth 7

7. Most oblique rows of teeth on fingers of pincers over-
   lapping (Tityus) 13

   Oblique rows of teeth on fingers of pincers not over-lapping.
   Southern Florida, California, Mexico (?)
   Isometrus europaeus .... Spotted Scorpion

8. More than 80 mm. long; usually dark brown or black without stripes 9

   Less than 70 mm. long; yellowish, reddish-brown or striped 10

   9. Fingers of pincers with 9 middle (and 1 short apical) rows of
teeth. Texas, Mexico. Centruroides nigrescens . . . . Black Scorpion

Fingers of pincers with 8 middle (and 1 short apical) rows of teeth.
Florida to California, and south to Brazil and Chile; West Africa.
Centruroides margaritatus . . . . .Margarite Scorpion

10. Ventral spine or tubercle at base of stinger absent.
California, Mexico (?). Centruroides exilicaudata . . . .
. . . . .Slender-Tailed Scorpion

Ventral spine or tubercle at base of stinger present,
often quite small 11

11. Abdomen without longitudinal stripes or rows of spots;
dorsal surface of abdomen granular. Arizona, Mexico.
Centruroides sculpturatus . . . . Deadly Sculptured Scorpion

Abdomen with longitudinal stripes or rows of spots 12

12. Black stripes. South Carolina to Kentucky to New Mexico
and Mexico. Centruroides vittatus . . . .
. . . . Common Striped Scorpion

Black row of spots. California, Mexico (?).
Centruroids californicus . . . . California Striped Scorpion

Black stripes. Arizona. Centruroides gertschi . . . . Striped-Back Scorpion

13. About 2 inches long; large ventral tooth at base of stinger absent.
California, Mexico (?). Tityus tenuimanus . . . . Little California Scorpion

Over 3 inches long; large ventral tooth at base of stinger present.
Southern Florida. Tityus floridanus . . . . Florida Scorpion

14. Dark reddish-brown, almost black; 2-2.75 inches long.
Texas, California, Mexico (?). Diplocentrus whitei . . . . . . .White's Scorpion

Reddish brown, not blackish; 1.6-2.2 inches long. Texas, California (?)
Mexico (?). Diplocentrus keyserlingi . . . . Keyserling's Scorpion

15. Middle area of pectines broken up into more than 8 small pieces,
the most of which are subcircular 16

Middle area of pectines more or less indistinctly broken up into
7 or less pieces 17

16. Movable finger of chelicera with a spine-like tooth ventrally;
large hairy scorpions (Hadrurus; the hairy scorpions) 18

Movable finger of chelicera without ventral tooth
(Vejovis, the devil scorpions). 20

17. Divisions of middle area of pectines unequal and few in number;
  stinger sometimes bulbous near base. California, Utah,
  Colorado, Virginia (?), Guatemala. <u>Anuroctonus</u> <u>phaeodactylus</u> . . . .
  . . . . Shiny-Stinged Scorpion

  Most divisions of middle area of pectines subequal and numbering
   over 5; stinger normal. California, Oregon.
   <u>Uroctonus</u> <u>mordax</u> . . . . Mordant Scorpion

18. Anterior portion of interocular triangle of a dark brownish
  to black color. Arizona, Utah. <u>Hadrurus</u> <u>spadix</u> . . . .
  . . . . .Black-Eyed Hairy Scorpion

  Anterior portion of interocular triangle light yellow or
   straw color 19

19. Over 2.8 inches long; reddish-brown; appendages and post-
  abdomen very hairy; pectines with 34-40 teeth. Nevada,
  Arizona, California, Mexico, Guatemala (?). <u>Hadrurus</u> . . . .
  <u>hirsutus</u> . . . . Giant Hairy Scorpion

  Under 2.4 inches long; olive gray; pectines with 25-32 teeth.
   Arizona, Mexico. <u>Hadrurus</u> <u>arizonensis</u> . . . . Arizona Scorpion

20. Claws with ridges or keels, granular · 21

  Claws without ridges or keels, smooth. 26

21. Caudal vesicle heavily setaceous. California. <u>Vejovis</u>
  <u>hirsuticauda</u> . . . . Hairy-Tailed Devil Scorpion

  Caudal vesicle almost bare 22

22. Ventral keels distinct on first two segments of post-
  abdomen; stinger subequal to vesicle in length 23

  Ventral keels absent or vestigal on first two segments of
   postabdomen; stinger not over 2/3 as long as vesicle 24

23. Postabdominal segments I and II broader than long.
  California. <u>Vejovis</u> <u>minimus</u> . . . . California Devil Scorpion

  Postabdominal segments I and II longer than broad 25

24. Middle dorsal keel of hand well developed; stinger longer than
  vesicle. Arizona, California, Utah, Nevada, New Mexico,
  Mexico. <u>Vejovis</u> <u>punctipalpis</u> . . . . Southwestern Devil Scorpion

  Middle dorsal keel of hand absent; stinger shorter than vesicle.
   California. <u>Vejovis</u> <u>yosemitensis</u> . . . . Yosemite Devil Scorpion

25. Integument smooth or finely granular; yellow-brown to greenish.
   Norh Dakota and Nebraska to Oregon and Arizona.
   Vejovis _boreus_ .... Northern Devil Scorpion

   Integument coarsely granular; dark reddish-brown. Texas,
   Mexico. _Vejovis_ _mexicanus_ .... Mexican Devil Scorpion

26. Postabdominal segments IV and V stouter than other post-
   abdominal segments; greenish or yellow with broad,
   indistinct, yellowish median stripe on dorsum of abdomen
   and four dark longitudinal lines on underside of post-abdomen.
   Texas to California and Mexico. _Vejovis_
   spinigerus .... Striped-Tailed Devil Scorpion

   Postabdominal segments IV and V slightly slenderer than
   other postabdominal segments 27

27. Claw slender, not swollen on inside, about twice as long as wide.
   New Mexico, Arizona, Mexico. _Vejovis_ _flavus._ .... Slender Devil Scorpion

   Claw not slender, markedly swollen, about one and one-half
   times as long as wide 28

28. Postabdominal segments III and IV without ventral sub-
   median keels. South Carolina to Texas. _Vejovis_
   carolinianus .... Southern Devil Scorpion

   Postabdominal segments III and IV with ventral submedian keels.
   Arizona, Mexico. _Vejovis_ _subcristatus_ .... Mottled Devil Scorpion

ORDER ARANEAE
(spiders)

General Characteristics

A spider can be recognized by its peculiar body organization, the <u>cephalothorax</u> <u>and abdomen</u> being <u>joined</u> together <u>by a slender</u> <u>pedicel or stalk</u> (Plate IV). The head may usually be distinguished although it is joined to the thorax. The eyes are simple, near the front of the head, normally eight in number, and may be grouped together on a tubercle, or separated across the head. In front, above the mouth, are the chelicerae, which are claw-like appendages that the spider utilizes to capture its prey. (Plate V.-D). A venom gland is located near the tip of the claw for the purpose of paralyzing or killing its victims (Fig. 11). These chelicerae are modified antennae comparable to the second antennae of the Crustacea, the first antennae having been lost, and distinguishable only in the embryo. Behind the head, the thoracic portion of the cephalothorax bears four pairs of legs. The abdomen is externally unsegmented, soft and usually rounded, but there is a great variation in its form. The true spiders generally have trachea in addition to book lungs for respiration. They open to the exterior by a single spiracle, or pair of spiracles on the abdomen. The book lungs open by means of one or two pairs of slits also situated on the abdomen. There are usually three pairs of spinnerets near the caudal end of the abdomen associated with the spinning of silken threads.
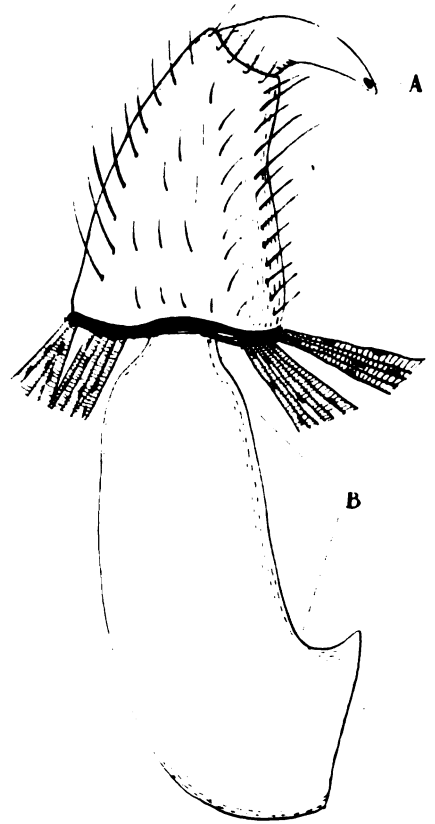
Figure 11.
Portion of the venom gland and chelicera of <u>Latrodectus</u>, Black Widow Spider. (A) Venom pore; (B) Gland. (Redrawn from Phisalix).

Geographical Distribution

Spiders are cosmopolitan in distribution, but the greater majority are found in the temperate and tropical zones. The black widow <u>Latrodectus</u> <u>mactans</u> (Fabr.) is found throughout the United States, Southern Canada, Cuba, Mexico and parts of South America. There are many other species of the genus <u>Latrodectus</u> that are found in various countries, all having potent venom. The black widow is estimated to possess venom many times as potent as that of a rattlesnake, and <u>L</u>. <u>indistinctus</u> Camb. of South Africa is said to have venom equal in toxicity to that of a cobra. The wolf spiders, genus <u>Lycosa</u> and the wandering spiders, genus <u>Ctenus</u>, are forms

35

with potent venom found in Brazil. <u>Loxosceles</u> <u>laeta</u>" (Nicolet), the house spider of Uraguay and Chili is a venomous species living in walls and closets of homes, hiding in bedding and clothing. <u>Loxosceles</u> <u>reclusus</u> Gertsch., a spider of the Midwestern United States, is a venomous species that occasionally bites man.

Life Cycle and Habits

Spiders lay their eggs in masses and generally cover them with silken egg-sacs. In a short time the eggs hatch, the young spiders remaining in the egg-sac for a long period of time, often for the duration of the winter in the Northern United States. Within the sac the young spiders may feed upon their brothers and sisters since they are cannibalistic. Eventually they make holes in the egg sac and escape, increase in size, molt several times with no marked change in form, and become adults.

Spiders feed chiefly on insects and small animals, but in the adult stage will devour other spiders. Females of a given species often destroy the males. They feed by sucking the body juices and predigested solid tissues from their victims. Spiders catch their prey in varied ways, some search for victims and pounce upon them, others hide in flowers catching insects as they enter, but the majority spin webs as traps. Once the prey is enmeshed in the web. the spider administers a lethal bite, then sucks and digests the body contents at leisure.

Relation to Man

Most spiders are harmless individuals which pay little or no attention to man. Occasionally man blunders into their homes and provokes an attack. Few have chelicerae that are strong enough to penetrate the human skin, and the majority of those that do, produce only temporary discomfort similar to a pin prick or the sting of a bee. Most species of even the large tarantulas are not considered dangerous. However the genus <u>Latrodectus</u> has venomous species in many tropical and temperate countries which cause serious disability or even death. One, the black widow, <u>L.</u> <u>mactans</u>, has caused many cases of serious illness and death. This species (Plate V.) is shiny black with orange or scarlet markings on the ventral portion of the abdomen in the form of an hour-glass. In addition the males and young females have scarlet spots on the dorsal side. They hide in old stumps, lumber, rock piles, trash heaps, ground holes, out-buildings, basements and under outdoor toilet seats.

Spider and scorpion venoms are similar in appearance being lemon-yellow in color, translucent, slightly acid, thick and oily. The black widow may cause symptoms similar to an acute surgical abdomen such as acute appendicitis or perforated ulcer. Other disorders that may be suspected are strangulated hernia, pleurisy, early pneumonia, tetanus, peritonitis, biliary and renal colic, tabetic crisis, food poisoning, and hysteria. The pain is said to be so intense that the patient is likely to consent to any operation that promises to relieve him.

PLATE V.
THE "BLACK WIDOW" SPIDER
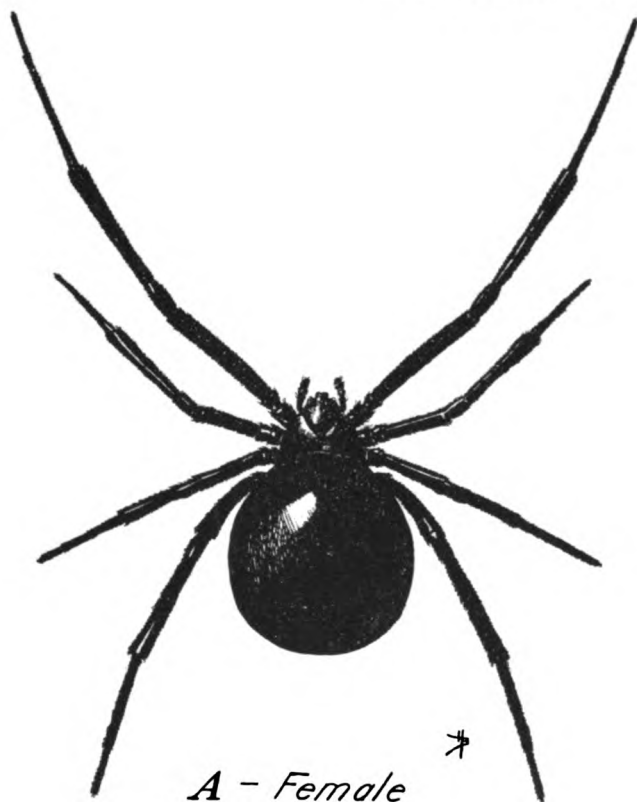
B - Under side
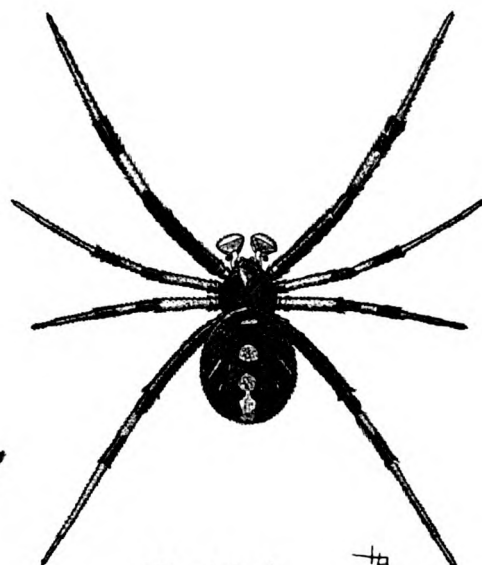
A - Female

C - Male
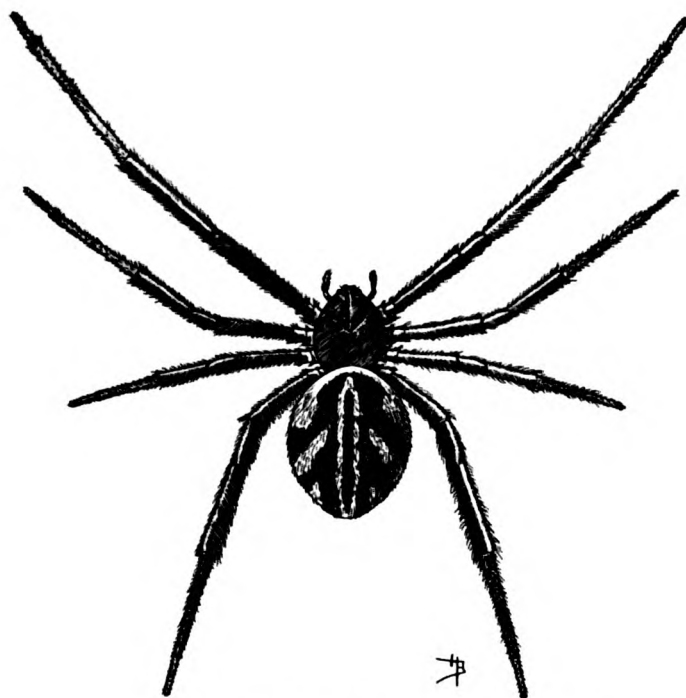
E - Immature female 37
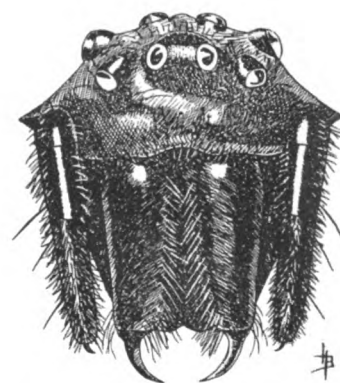
D - Head of female
(Front view)

After Billman

The symptoms in soldiers during the Second World War were described by Frank (1942) as a sharp stinging bite with initial local pain lasting for three to five minutes. Return of pain in about 15 minutes which spreads along the lymphatic drainage. When the toxin reaches the general circulation it spreads rapidly giving rise to systemic symptoms within one-half to three-fourths of an hour. The predominant sympton is muscular with an agonizing, cramp-like abdominal pain accompanied by perspiration, nausea, vomiting, delirium, and dyspnea. The abdomen is in a definite spasm and is board-like. Twitching of the face and neck muscles is frequent, and in all cases there is a fine tremor of the fingers and hands. The heart rate is either normal or slightly accelerated, blood pressure elevated, but no elevation of temperature. The day after the bite there is a burning and stinging of the soles of the feet which is a symptom that is almost invariably present, although it may be mild. All symptoms generally abate after 24 hours leaving the patient weak and exhausted.

If there is no valid history of an insect or spider bite, arachnidism should be suspected if the temperature and pulse is normal, the patient is not in shock, if there is generalized muscle pain and spasm, abdominal pain and rigidty without pointed tenderness, emotional instability, and hyperactive reflexes.

Some Dangerous Spiders. (Courtesy Department Health, Education and Welfare, Public Health Service, Communicable Disease Center, Atlanta, Ga.)

SCIENTIFIC NAME (Type of Venom)	COMMON NAME (Mortality)	DISTRIBUTION
Atrax robustus, A. formidabilis	funnel webs (43% mortality based on very limited data)	Australia
Glyptocranium gasterocanthoides (neurotoxic)	pododora	Peru, Chile, Argentina
Chiracanthium diversum	none	South Pacific to Hawaii
Latrodectus curacaviensis	none	North America to South America
Latrodectus cocinnus	none	South Africa
Latrodectus geometricus (neurotoxic)	brown widow	North America to South America
Latrodectus hasselti	katipo (6% mortality in limited sample)	West Africa, Philippines to New Zealand
Latrodectus indistinctus (haemolytic)	Kroppie	South Africa
Latrodectus mactans (neurotoxic)	black widow (5% mortality in untreated cases)	Canada to Chile
Latrodectus menovodi	vancohs	Madagascar
Latrodectus tredecimguttatus	Malmignatte or Kurakurt	South Europe
Loxosceles laeta (haemolytic)	false-hackled band spinner	Chile
Loxosceles reclusus (haemolytic)	none	Midwestern United States
Lycosa raptoria	South American wolf spider	South America, Central America
Sericopelma communis	black tarantula (bite very painful, rarely fatal)	Panama

ORDER ACARINA
(ticks and mites)

General Characteristics

The majority of the ACARINA are round or oval, dorso-ventrally depressed forms with the <u>head, thorax, and abdomen fused</u> to form a single region (Plate VI). They differ from the arachnids previously discussed in the lack of visible segmentation of the body. The anterior portion is modified to form a <u>capitulum</u>, made up of a central <u>hypostome</u>, and paired <u>chelicerae and palpi</u>, which functions in attachment and obtaining food (Fig. 12). Eyes, when present, are normally located on the margin of the scutum, or on the ventral surface in folds. The organs of respiration, when present, are trachea opening through spiracles located in pairs or singly. Those that lack respiratory organs (certain of the mites) breathe through the body wall directly. Four pairs of legs are present in most of the adults.

The Order Acarina includes two groups of organisms, the ticks and the mites. <u>Mites</u> are usually small forms in which the <u>hypostome is hidden and unarmed</u>, while <u>ticks</u> are larger forms in which the <u>hypostome is exposed and armed</u> with teeth or hooks (Fig. 12, A & B). In a sense, ticks are merely one superfamily of very large mites, but for convenience the ticks and mites will be considered separately. They may be differentiated as follows:

<u>Mites</u>	<u>Ticks</u>
1. Body usually clothed with long hairs.	1. Body clothed with short hairs or bare.
2. Hypostome hidden and unarmed.	2. Hypostome exposed and possessing teeth.
3. Usually small forms, many microscopic.	3. Larger forms, all macroscopic.
4. Body texture membranous in appearance.	4. Body texture leathery in appearance.
5. Pedipalps almost lacking in segmentation in some forms.	5. Pedipalps prominent and distinctly segmented.
6. Chelicerae reduced to blades, rods, or pincer shaped.	6. Chelicerae heavily chitinized, bearing strong cutting teeth at their distal end.

PLATE VI.
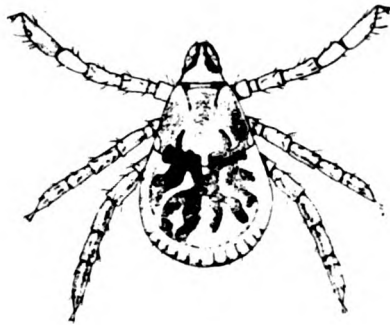
LARVA
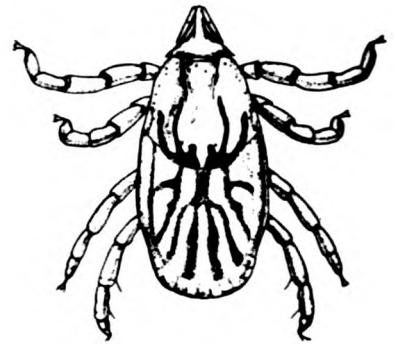
NYMPH

EGG MASS

MALE
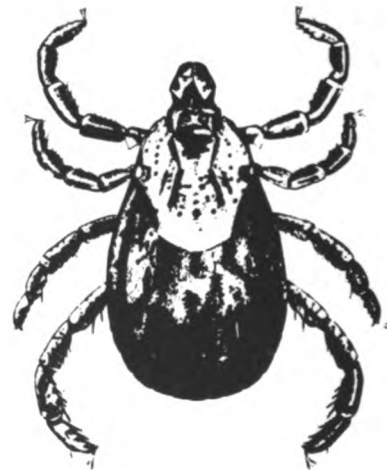
FEMALE

LIFE HISTORY STAGES OF AMERICAN DOG TICK
(Dermacentor variabilis)

DHEW-PHS-CDC   ATLANTA, GA.

JUNE, 1954

40
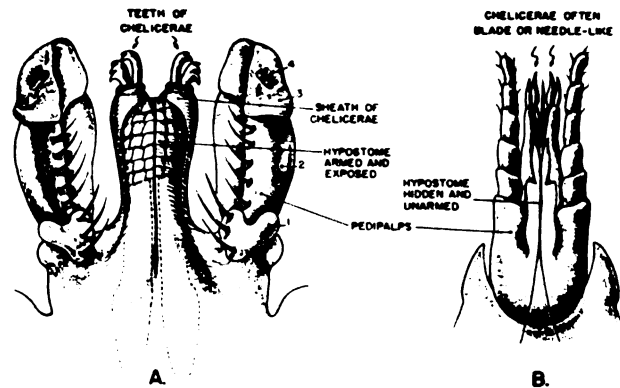
Figure 12.
Mouth parts of: A. Ticks. B. Mites.
Ventral aspect (schematic).

THE TICKS

Geographical Distribution

Ticks are found throughout the world, but are most numerous in the tropics and subtropics.

Temperate climates harbor fewer species of the argasids (soft ticks) and there are very few in the arctic. They feed on birds, bats and less commonly, on other animals. The ixodids (hard ticks) are associated with terrestrial vertebrates through-out the world, attacking birds, reptiles, amphibians and mammals.

Life Cycle and Habits

There are four stages in the development of a tick: Egg, larva, nymph, and adult (Plate VI).

Egg: The eggs are laid on the ground, in the cracks and crevices of houses, or in the nests and burrows of animals. The adult female hard tick lays a single batch of several thousand eggs and dies. The soft tick on the other hand, lays small lots several times. The period of incubation varies from two weeks to several months.

Larva or seed tick: This is the stage which issues from the egg. It is very small and has only six legs. Some species crawl up vegetation and await the passing of a suitable host such as a small rodent or bird, others hunt actively for a host. They attach themselves to the host, insert their mouth parts, become engorged with blood in a few days, drop to the ground in most cases, molt and become eight legged nymphs. There are some, e.g., the southern cattle tick, Boöphilus annulatus (Say), that are one-host ticks, remaining on the host during development. The larvae of two species of Ornithodoros in the Sudan are non-motile and take no food (Hoogstraal 1956).

41

<u>Nymph</u>: The eight-legged nymph differs from the adult in being sexually imma ture and in lacking a genital opening. It has habits similar to those of the larva, attaching itself to a host animal, engorging, dropping off to shed its skin, and becoming an adult. The transformation to the adult stage may be delayed for some time. The life cycle ranges from less than a year to at least three years. Engorgement is necessary between each life stage.

<u>Adult</u>: Adults also have eight legs of six segments each; coxa, trochanter, femur, tibia, metatarsus, and tarsus (Fig. 32). The male and female genital pore is found directly behind the basis capituli. In most species the genital grooves extend from the genital pore to the caudal margin of the body. The anus is near the caudal end of the body behind the fourth pair of legs, between the genital grooves. In the hard ticks the spiracles are borne on plates just behind the fourth pair of legs (Fig. 15), and between the third and fourth coxae on the sides of the body in the soft ticks (Fig. 27).

Some adult ticks require a blood meal before copulation; others do not. Adult female ticks feed once, or several times, before oviposition. The argasid adults engorge several times, each usually followed by a rest for digestion. The body is leathery, in the hard ticks, and becomes greatly distended when the female engorges (distention occurs in both male and female soft ticks).

Both sexes suck blood after which they copulate, and the male dies. The females then drop to the ground for oviposition.

Much of the life cycle of ticks is spent awaiting suitable hosts, except in the case of the one-host ticks. Ticks are found predominantly along animal paths, trails and roads in shrub covered areas. The soft ticks are usually found in drier situations than the hard ticks.

<u>Relation to Man</u>

All ticks are parasitic during some period of their lives. They are annoying pests and in addition they are transmitters of the causative agents of many diseases. Their bites are irritating, and often when they are removed forcibly, the mouthparts remain in the skin resulting in infection causing ulceration or septicemia. The young seed ticks are often very numerous and can cause irritation similar to chiggers. In three regions of the world, South Africa, Australia, and Northwestern United States there occurs in man and in certain domestic animals a condition known as <u>tick paralysis</u>. This is a progressive ascending flaccid motor paralysis following the bite of the female tick, especially severe when attachment is on the back of the neck or at the base of the skull. The exact etiology of this condition still remains undetermined, but the prevailing opinion is that a toxic substance in the tick saliva is responsible for the paralysis. Such paralysis does not begin until nine or more days after the tick becomes attached, and it disappears rapidly if the tick is located and removed. Paralysis affects young children principally.

The importance of ticks as transmitters of disease agents long has been recognized. Among the more important diseases associated with ticks are Rocky Mountain spotted fever, Sao Paulo fever, relapsing fever, and tularemia. For a more complete list, see the summaries at the end of the manual.

Ticks are usually regarded as blood-sucking ectoparasites of vertebrates, although it is worth pointing out that many of them do not remain on the host after the blood-sucking act is completed and are, stricly speaking, free-living organisms during the periods when they molt and lay eggs. There are two families of ticks, as mentioned above, the IXODIDAE, or hard ticks, and the ARGASIDAE, or soft ticks; and, since their habits vary, they will be considered separately.

Classification of Ticks of Medical Importance

Mouth parts situated forward and beyond the anterior border,
visible in dorsal aspect; scutum present .... IXODIDAE
(hard ticks)

Mouth parts situated ventral to the anterior extremity, not
visible in dorsal aspect; scutum absent .... ARGASIDAE
(soft ticks)

FAMILY IXODIDAE

General Characteristics

The hard ticks are so-called because they possess a hard back-- shield or scutum. This covers the entire dorsal surface of the male, but extends over only a small part of the anterior dorsum of the female (Fig. 14). The capitulum projects at the anterior extremity, so that the mouth parts can be seen from above. Its structure is rather complicated. An illustration is provided to aid the student in the identification of the parts (Fig. 13).

Palpi long --- the second joint longer than broad
(Ixodes , Hyalomma , Amblyomma , Aponoma)

Teeth of chelicera
Hypostome
Cheliceral sheath

4th segment
3rd segment
2nd segment
1st segment

Ixodes sp.

Palpi short --- the second joint broader than long
(Haemaphysalis , Dermacentor , Rhipicephalus , Boöphilus, etc.)

Rhipicephalus sp. Dermacentor sp. Boöphilus sp.

Figure 13
Ventral aspect of the capitula of some hard ticks

43

Key to the Principal Genera of Ixodidae

1. Anal groove running in front of anus; pedipalps usually spatulate
    in form; male with numerous ventral plates .... Ixodes

    Anal groove either running behind anus or so indistinct that it
    cannot be seen clearly 2

2. Mouth parts about as long as basis capituli; second joint of pedi-
    palps not much longer than wide 3

    Mouth parts much longer than basis capituli; second joint of
    pedipalps much longer than wide 8

3. Anal groove plainly visible; festoons usually present 4

    Anal groove absent or indistinct; festoons absent 7

4. Second joint of pedipalps laterally produced, so that it extends
    beyond the edges of the basis capituli; eyes absent .... Haemaphysalis

    Second joint of pedipals not laterally produced; eyes present 5

5. Basis capituli rectangular in dorsal view; scutum usually ornate;
    male without ventral plates; fourth coxa of male much larger
    than the others .... Dermacentor

    Basis capituli hexagonal in dorsal view; scutum usually not ornate 6

6. Male without ventral plates and with fourth coxa much larger
    than the others .... Rhipicentor

    Male with ventral plates and with fourth coxa not much
    larger than the others .... Rhipicephalus

7. Male with forked preanal plate; joints of fourth pair of legs
    greatly swollen .... Margaropus

    Male with paired adanal and accessory plates; joints of
    fourth pair of legs normal .... Boöphilus

8. Eyes absent; males without ventral plates .... Aponomma

    Eyes present 9

9. Eyes submarginal; males with ventral plates .... Hyalomma

    Eyes marginal; males without ventral plates .... Amblyomma

44

These ticks attach themselves firmly to their hosts during the blood-sucking act and may remain upon them for days, or even weeks, before engorgement is completed. The larvae and nymphs take only one blood meal each, and the adult female takes only a single enormous blood meal before dropping off the host to digest the blood and lay a single large batch of eggs. Most hard ticks have either two or three hosts during their development, although one or two species have only a single host.
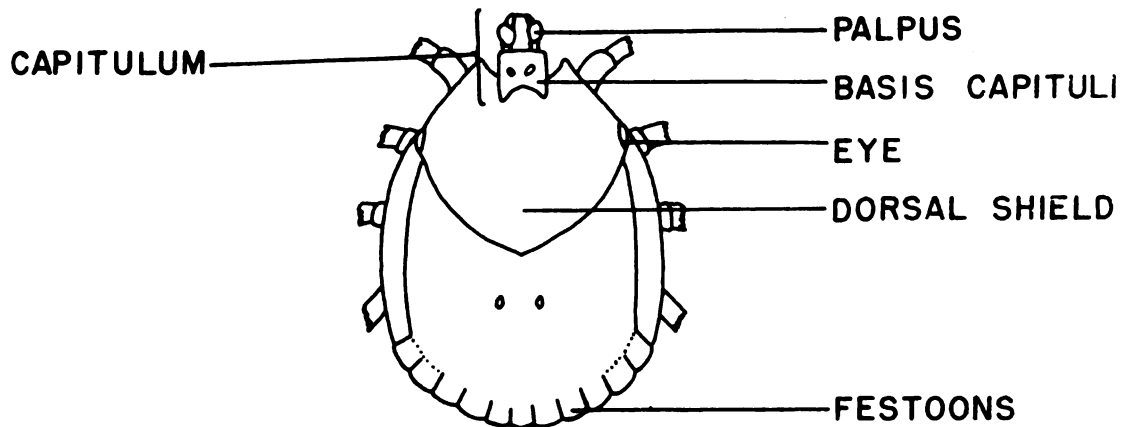
FIGURE 14   **DORSAL ASPECT OF FEMALE HARD TICK**
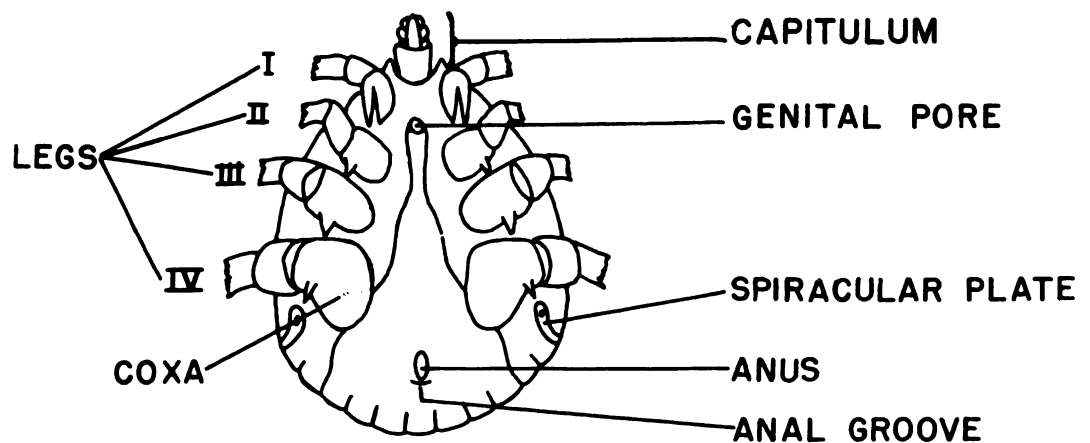
FIGURE 15   **VENTRAL ASPECT OF MALE HARD TICK**

DORSAL ASPECT OF CAPITULA OF HARD TICKS
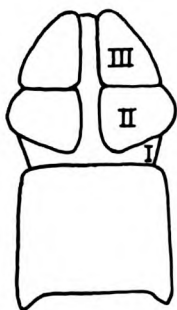
DERMACENTOR
FIGURE 16
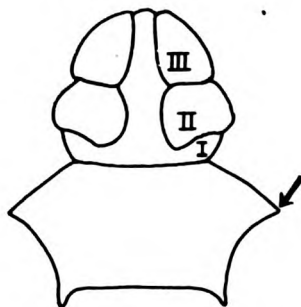
RHIPICEPHALUS
FIGURE 17

HAFMAPHYSALIS
FIGURE 18

SPIRACULAR PLATES OF *DERMACENTOR*

dorsal prolongation
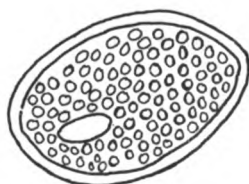
D. albipictus
FIGURE 19
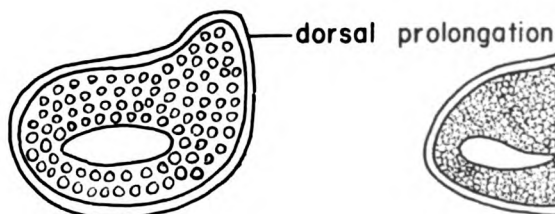
D. andersoni
FIGURE 20
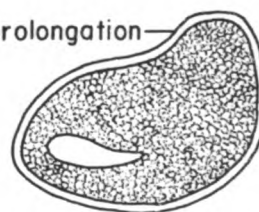
D. variabilis
FIGURE 21

AMBLYOMMA

capitulum and dorsal shield
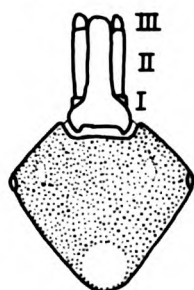
Leg IV
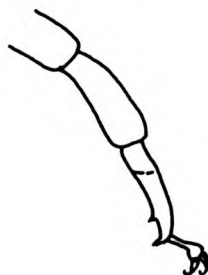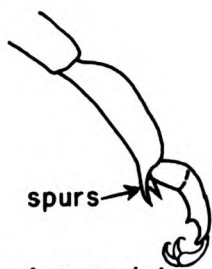
VENTRAL ASPECT OF MALE *IXODES*

FIGURE 22

A. americanum

spurs

FIGURE 23

A. maculatum

capitulum
external spur
internal spur
genital opening
spiracular plate
median plate
anal groove
adanal plate
anus
anal plate
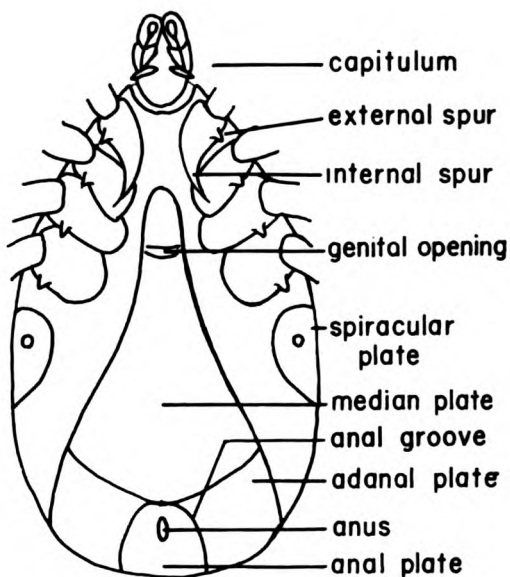
FIGURE 24

Discussion of Genera of Medical Importance

Genus Ixodes

Ixodes scapularis Say, the black-legged tick, attacks man as well as cattle, dogs, sheep, deer, and fox in the United States. It mainly annoys man, and is not known to carry disease. Anastos (1957) lists several Ixodes species in the U.S.S.R. that are involved in the transmission of such diseases as tularemia, Babesia bovis Starcovici, spring-summer encephalitis, and louping ill of sheep.

Genus Haemaphysalis

The rabbit tick, Haemaphysalis leporis-palustris Packard, spreads tularemia and spotted fever in animals, maintaining the natural reservoirs. Anastos lists species of this genus as implicated in the transmission of spring-summer encephalitis, tick-borne typhus, Babesia bovis, and brucellosis of animals in the U.S.S.R. According to Hoogstraal (1956), the only African haemaphysalid of known importance is H. l. leachii (Audouin), which transmits boutonneuse fever (tick typhus) of man and malignant jaundice of dogs.

Genus Dermacentor

Dermacentor variabilis (Say), the American dog tick, is a vector of spotted fever, tularemia and bovine anaplasmosis in the United States. Dermacentor andersoni Stiles, the Rocky Mountain wood tick, transmits Rocky Mountain spotted fever, Colorado tick fever, and tularemia. Dermacentor occidentalis Neum. also is a vector of tularemia. In the U.S.S.R., Anastos reports species of this genus to be the vectors of tularemia, tick-borne typhus, piroplasmosis, anaplasmosis, and equine encephalomyelitis. Other diseases were transmitted experimentally.

Genus Rhipicephalus

In the United States the genus Rhipicephalus (Fig. 17), which includes the species sanguineus (Latreille), the brown dog tick, very seldom attacks man and does not appear to be of medical importance. It does, however, drop off dogs and often heavily infests homes. In the U.S.S.R. Anastos reports the genus to be implicated in the transmission of piroplasmosis, anaplasmosis, tularemia, and Marseilles fever. According to Hoogstraal, species of this genus are numerous in Africa being implicated in the transmission of such diseases as East Coast fever of cattle, Boutonneuse fever and Indian tick typhus of man, Nairobi sheep disease, redwater fever (Babesia bigemina, Smith and Kilbourne), equine piroplasmosis, and spirochetosis.

Genus Boophilus

The cattle tick, Boophilus annulatus, is a vector of Texas cattle fever. In the U.S.S.R. Boophilus calcaratus (Birula) transmits piroplasmosis of cattle and

spirochetosis. In Africa, Hoogstraal reports <u>Boophilus decoloratus</u> Koch as transmitting red water fever and gallsickness of cattle, and spirochetosis of cattle, horses, sheep and goats.

<u>Genus Amblyomma</u>

In the genus <u>Amblyomma</u> there are only a few species in the United States, the majority being found in the tropics. <u>A</u>. <u>americanum</u> (Linn.) is under suspicion as a vector of "Q" fever, spotted fever and tularemia. It is found on dogs and cattle in the Southern States. <u>A</u>. <u>maculatum</u> Koch, the Gulf Coast tick is concerned with screwworm in domestic animals. <u>A</u>. <u>hebraeum</u> Koch is considered to be a vector of tick typhus in South Africa and <u>A</u>. <u>variegatum</u> (Fabr.) is naturally infected with "Q" fever in French Equatorial Africa near the Sudan border. Several species of the genus are associated with the transmission of veterinary diseases in Africa.

Many species of the hard ticks are implicated in tick paralysis in different parts of the world, and many of both families have been found to transmit diseases experimentally.

Key to Important Species of Adult Ixodidae of the U. S.*

1. Ornate ticks, with some white markings on dorsal shield (Figs. 22, 23) 2

    Inornate ticks, without white markings on dorsal shield 6

2. Palpi short, about as long as basis capituli; second segment of palpus
    about as long as wide (Fig. 16) Genus DERMACENTOR 3

    Palpi long, much longer than basis capituli; second segment of palpus
    about twice as long as wide. (Figs. 22 and 23) Genus AMBLYOMA 5

3. Spiracular plate without dorsal prolongation (Fig. 19)
    Winter tick .... Dermacentor albipictus

    Spiracular plate with dorsal prolongation (Figs. 20, 21).................... 4

4. Goblets of spiracular plate large and less numerous; Rocky Mountain
    species (Fig. 20) ... Wood tick ....·....... D⸱rmacentor andersoni

    Goblets of spiracular plate very small and numerous; east of the
    Rockies and on the Pacific coast (Fig. 21)
    American dog tick .... Dermacentor variabilis

5. Next to last segment of second, third, and fourth pairs of legs without
    paired terminal spurs; female with a distinct pale marking near
    posterior end of dorsal shield (Fig. 22)
    Lone star tick .... Amblyomma americanum

    Next to last segment of second, third, and fourth pairs of legs with
    long, paired terminal spurs; female with more diffuse marking
    on dorsal shield (Fig. 23).... Gulf coast tick .... Amblyomma maculatum

6. Sides of basis capituli laterally produced, distinctly angulate (Fig. 17)
    eyes present on sides of scutum (Fig. 14) 7

    Sides of basis capituli not laterally produced, more or less parallel
    (Fig. 18); eyes absent.. 8

7. Fore coxa deeply cleft; festoons present; easily seen in unengorged
    specimens; anal groove distinct in unengorged specimens; (principally
    on dogs or in houses)..Brown dog tick............Rhipicephalus sanguineus

    Fore coxa not deeply cleft; festoons absent; anal groove indistinct;
    (on cattle and deer)...Cattle tick .... Boophilus annulatus

8. Second segment of palpus laterally produced (Fig. 18); anal groove
    beꜰind anus, not attaining posterior margions of body as in Fig. 15. ....
    .... Rabbit tick, Haemapꜰysalis leporispalustris

    Second segment of palpus not laterally produced; anal groove extending
    as an inverted U from in front of anus to posterior margins of tne
    body (Fig. 24) .... Genus Ixodes

FAMILY ARGASIDAE

General Characteristics

The soft ticks are so-called because they lack the rigid scutum, a condition which causes the two sexes to appear similar (Fig. 33). The mouth parts are located beneath the anterior extremity of the body in such a manner that they can not be seen from above (Figs. 33 and 34). The spiracles are located above the third and fourth pairs of legs on the sides of the leathery, wrinkled body. The adults do not increase greatly in size while engorging. The principal hosts of the argasids are birds, domestic animals, bats and other small mammals. They feed intermittently at night in the burrows of animals, chicken houses, bat roosts, caves, and in human dwellings. The adult female lays her eggs following a blood meal, producing 500 to 1,000 eggs during her lifetime. They have much the same habits as bedbugs, hiding in cracks and crevices, or in the nests of their hosts during the daytime. The larvae and nymphs generally feed several times before molting. Soft ticks have many hosts which increases their potentialities as vectors of disease organisms.

Discussion of Genera of Medical Importance

Genus Argas: Argas persicus (Oken) (fowl tick, blue bug), is found in the Southern United States, Europe, Asia, Africa, and Australia. It is commonly found on fowl and is a vector of fowl spirochetosis and piroplasmosis. These ticks may live for months or years without blood awaiting an opportunity for a blood meal. They are troublesome in that they readily attack man.

Genus Otobius: This genus contains the spinose ear tick Otobius megnini (Dugès), common in the ears of horses or cattle in the South Western United States. It has been reported as infesting the ears of man causing severe pain.

Genus Ornithodorus: The genus Ornithodorus (Fig. 34) contains the most important argasids from the medical standpoint. Some species are found in parts of both the Eastern and the Western Hemispheres. Ornithodorus turicata (Dugès), found in Texas, Kansas, Oklahoma, New Mexico and Mexico, is a vector of relapsing fever, which it passes on to its young. O. parkeri Cooley of Nevada, Utah, and California, is a vector of relapsing fever in California and possibly in other States. It also harbors the spotted fevers of the United States, Columbia and Brazil with transovarial transmission of the Rickettsias to the fourth generation. O. talaje (Guérin-Meneville) is also a vector of relapsing fever, in Guatemala, Panama and Columbia, and possibly in the United States since the spirochetes have been recovered from

50

suttural line
discs
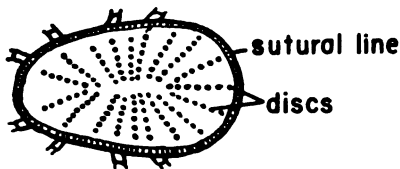
FIGURE 25

DORSAL ASPECT
OF *ARGAS*
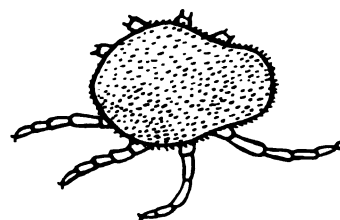
FIGURE 26

DORSAL ASPECT OF
OTOBIUS NYMPH

anterior eye
capitulum
spiracle
posterior eye
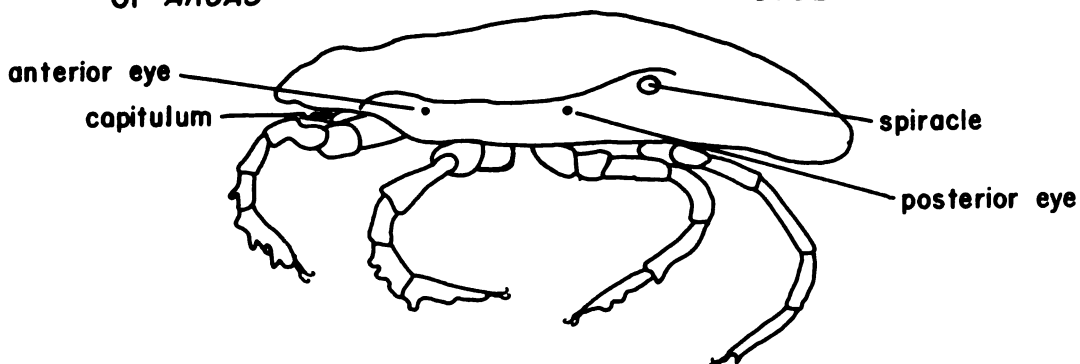
FIGURE 27   LATERAL ASPECT OF *ORNITHODOROS*

LEGS OF *ORNITHODOROS*

LEG I   LEG IV

FIGURE 28   *O. hermsi*

FIGURE 29   *O. taloje*

FIGURE 30   *O. coriaceus*

FIGURE 31   *O. turicata*

SUBAPICAL
DORSAL
PROTUBERANCE
TARSUS
DORSAL
HUMPS
METATARSUS
TIBIA
FEMUR
TROCHANTER
COXA
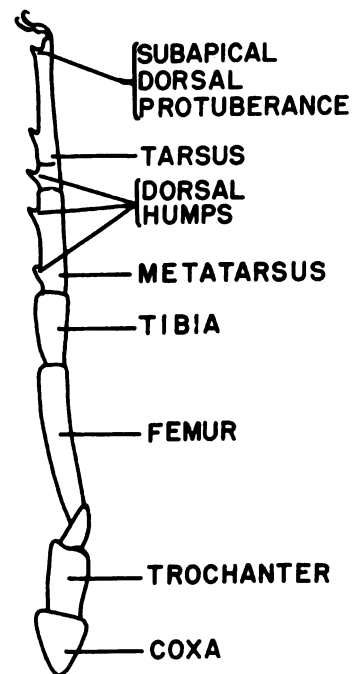
DIAGRAM OF A LEG
FIGURE 32

ticks in that area. O. rudis Karsch, the most important vector of relapsing fever in Panama and South America, is a tick having man as its only known host. O. moubata (Murray) widely distributed in Africa, is the most important vector of relapsing fever there. O. erraticus (Lucas) also of North Africa, is the vector or relapsing fever in Spain and Portugal. O. coriaceus Koch of California and Mexico does not carry disease, but has a vicious bite. O. verrucosus Olenev of the North Caucasus is thought to be concerned in the transmission of relapsing fever. O. tholzani (Laboulbene et Mégnin) is a vector of relapsing fever in the U.S.S.R., Africa, and Cyprus.
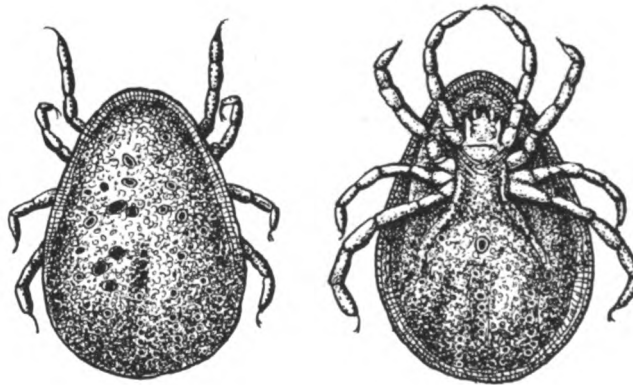
Figure 33
Dorsal and ventral views of Argas
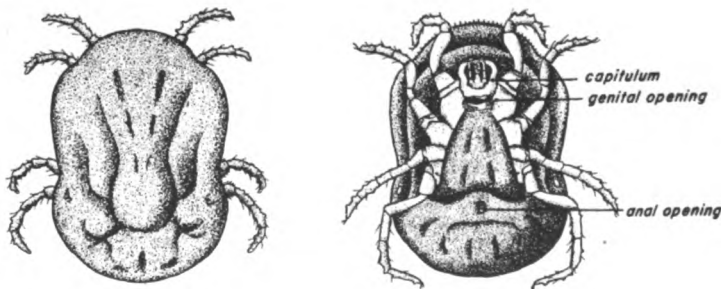
Figure 34
Dorsal and ventral views of Ornithodoros

Key to Important Species of Adult Argasidae of the U. S.*

1. Margin of body with a definite sutural line separating
dorsal and ventral surfaces; dorsal surface with
conspicuous "discs" arranged somewhat in radiating
lines (Fig. 25) ......Fowl tick .... Argas persicus

   Margin of body lacking the definite sutural line, thick
and rounded 2

2. Hypostome with well-developed teeth; integument not
spinose ...... Ornithodoros 3

   Hypostome of adult vestigial or without effective teeth;
integument of nymph (stage usually seen) spinose (usually
on cattle or horses) (Fig. 26) ......Spinose ear tick...... Otobius megnini

3. Strong dorsal humps absent on all tarsi (Figs. 28, 29) 4

   Strong dorsal humps present on tarsi of first, second, and
third legs (Figs. 27, 31) 5

4. Cheeks absent .... Ornithodoros hermsi

   Cheeks present .... Ornithodoros talaje

5. Eyes present on sides of body above second and third
coxae (Fig. 27); tarsus of fourth leg with a prominent,
pointed subterminal spur (Fig. 30) .... Ornithodoros coriaceus

   Eyes absent; tarsus of fourth leg without such subterminal spur 6

6. Mammillae large, relatively few and not crowded (Fig. 31)
tubercles in mid-dorsal region about 10 per linear mm;
hypostome over 1/2 mm. long – Southwestern U.S. and
Mexico north to Kansas and Florida .... Ornithodoros turicata

   Mammillae small, crowded, and numerous tubercles in mid-
dorsal about 18 per linear mm.; hypostome less than 1/2
mm. long – Pacific Coast and Rocky Mountain States... Ornithodoros parkeri

*Adapted from D. H. E. W. - P. H. S. - C. D. C., Atlanta, Georgia

53

PLATE VII

PICTORIAL KEY TO GENERA OF ADULT TICKS IN UNITED STATES

Capitulum inferior; scutum absent
FAMILY ARGASIDAE

Capitulum anterior; scutum present
FAMILY IXODIDAE

CAPITULUM

CAPITULUM

SCUTUM

Ventral   Dorsal

Female, dorsal   Male, dorsal

Margin of body with definite sutural line

Margin of body thick, rounded, without definite sutural line

Anal groove either behind anus, indistinct, or absent

Anal groove in front of anus

SUTURAL LINE

ANUS

ANAL GROOVE
ANUS

ARGAS

IXODES

Hypostome with well-developed teeth. Integument mamillated

Hypostome vestigial or without effective teeth. Integument tuberculated or granulated

Mouthparts as long as basis capituli. Second segment of palpi as long as wide

Mouthparts much longer than basis capituli. Second segment of palpi twice as long as wide

HYPOSTOME

SECOND SEGMENT OF PALPI
BASIS CAPITULI

ORNITHODOROS

AMBLYOMMA

Integument of adult granular, of nymph (stage usually seen) very spinose. Hypostome of adult vestigial. Usually on cattle, horses, or rabbits

Integument of adult and nymph tuberculated. Hypostome of adult scoop-like. Associated with bats.

Second segment of palpi not laterally produced

Second segment of palpi laterally produced

SECOND SEGMENT OF PALPI

ANTRICOLA

HAEMAPHYSALIS

OTOBIUS

Basis capituli laterally produced

Basis capituli not laterally produced

BASIS CAPITULI

Fore coxa not deeply cleft

Festoons absent. Anal groove indistinct

Fore coxa deeply cleft

Festoons present. Anal groove distinct

Festoons eleven

Festoons seven

ANAL GROOVE

FESTOONS

BOOPHILUS

RHIPICEPHALUS

DERMACENTOR

ANOCENTOR =(OTOCENTOR)

54

DHEW-ATLANTA,GA.

THE MITES

Geographical Distribution

Mites are cosmopolitan in distribution. There are over two hundred families, many of which are parasitic on plants and animals. Their habitat ranges from plant galls, rubbish, the soil and under stones, to fresh and sea water.

Life Cycle and Habits

As in the ticks, mites have four stages in their development -- egg, larva, nymph, and adult. They are very small, barely visible to the unaided eye. Nearly all species lay eggs, although a few retain the eggs within the body until hatched, a phenomenon known as ovoviviparity. From the egg, there emerges a six-legged larva (hexapod larva) which usually molts in a short period of time and becomes an eight-legged nymph (octopod nymph). After another short period the nymph, in turn, molts and the fully developed adult appears. The life cycle may be as short as seven days, and in many species it is less than a month. The mouth parts are, in general, similar to those of the ticks, but are quite varied in structure. The parasitic species usually have piercing chelicerae. The eyes are simple, consisting usually of one or more pairs. Respiration, as in the ticks, is predominantly tracheal, with the exception of those that absorb oxygen directly through the integument. Food consists of fresh or decaying organic matter, plant juices, animal tissues, skin or blood.

Relation to Man

Mites as a group are free living, but many are parasitic. The parasitic forms produce a mild to severe dermatitis, often followed by allergic reactions. The feeding habits of mites have affected the common names given to the various types of pruritus caused by them. Thus "grocer's itch" results from mites that feed on cereals and cheeses, and "straw itch" is caused by those living on insects in grain, straw or hay. Some mites are the etiological agents of mange and scabies of man and animals. One genus contains species involved in the transmission of the rickettsial infection variously known as tsutsugamushi, Japanese river fever or scrub typhus. Others are the natural vectors of rickettsialpox, or have been experimentally implicated in the transmission of endemic typhus, St. Louis strain of encephalomyelitis, equine encephalomyelitis, or Newcastle disease of chickens. The importance of the mites as natural vectors may be questionable.

Important Families

Sarcoptidae (mange mites or itch mites).   These mites attack birds and mammals often producing skin diseases. Sarcoptes scabiei (DeGeer) (Fig. 35) causes sarcoptic mange of man. They produce intradermal burrows in which a total of 10 to 25 eggs are deposited at intervals over a period of fourteen days. The female dies at the end of the burrow when oviposition is completed. After an incubation period of three to four days the larvae hatch and continue the burrowing, depositing fecal material as they progress and causing vesiculations followed by pruritus. The area is thus rapidly increased, the larvae molting three times and reaching maturity in about ten days. The itching caused by the tunneling larvae leads to scratching which produces serous exudation leading to a characteristic rash with possible secondary infection. This mange is acquired by close contact with infested persons.

2 STOUT BRISTLES ON
HEAD DIAGNOSTIC OF GENUS

EGGS

DORSAL

FORE PAIR LEGS
EXTEND BEYOND
MARGIN OF ABDOMEN

SHORT HIND PAIR LEGS

VENTRAL

ADULT FEMALE IN EPIDERMAL
LAYER OF SKIN

EXCREMENTOUS MATERIAL

EGGS

SECONDARY BURROWS OF LARVAE

SKIN
ENCRUSTATIONS
OF SCABIES
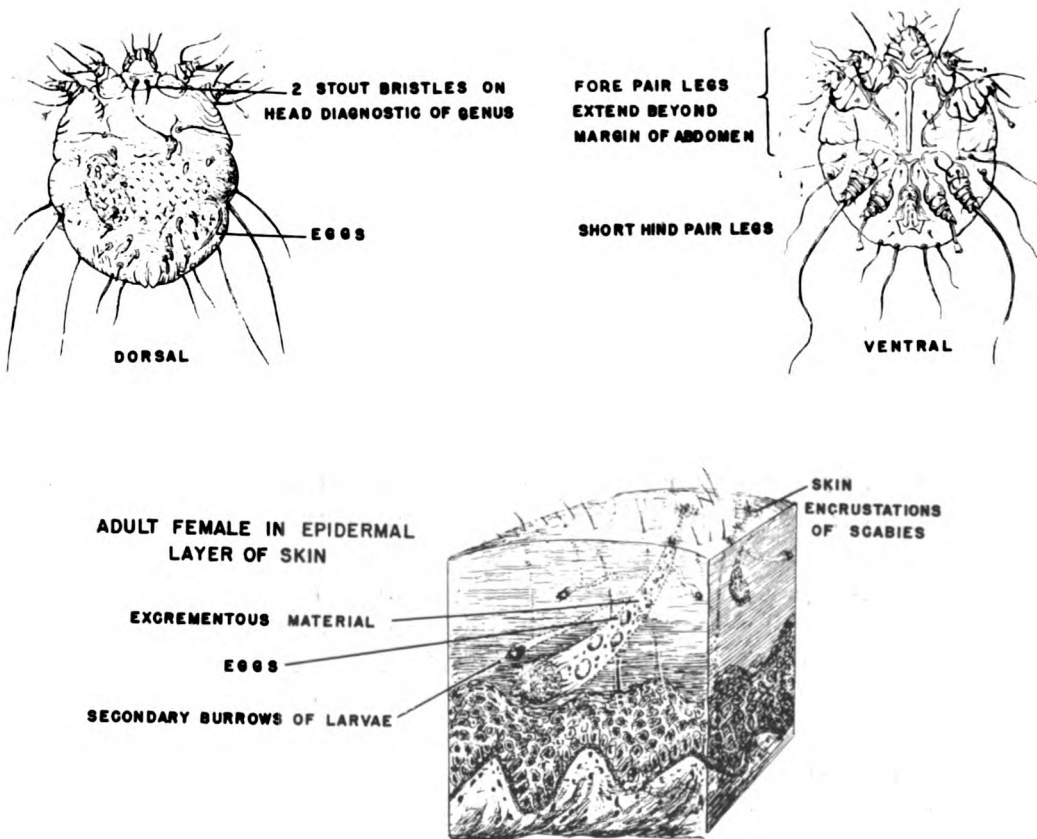
Figure 35

Sarcoptes scabiei and its burrows in the skin

56

Trombicula (chiggers, harvest mites, redbugs). The eggs of the trombiculids are laid on the ground, the young larvae attaching to a passing vertebrate host (including man) by their hooked mouth parts. These larvae, instead of burrowing, insert their mouth parts in the skin, usually close to a hair, and inject an irritating secretion which dissolves the tissues that are used for food. Severe itching results which lasts for several days after the larvae have dropped off or have been removed. Infection with tsutsugamushi or a secondary infection from scratching may result. Tsutsugamushi is the most important mite-borne disease. It occurs in North Australia, New Guinea, Bougainville Island, Indonesia, Malaya, Burma, India, Philippine Islands, Formosa, Japan, China, Indo China, Thailand, Ceylon, Sumatra, New Britain, and the Northern Hebrides. It is a rickettsial infection transmitted by larval trombiculid mites. The adults of this group are predaceous on small arthropods and their eggs.

Trombicula akamushi (Brumpt) is the important vector of tsutsugamushi disease in Japan, Malaya, and Sumatra (Fig. 36). Trombicula deliensis Walch has also been incriminated in Malaya and Sumatra, and other species of Trombicula may also be involved. These larval mites are hairy, orange-red forms, scarcely visible to the naked eye, and about 400 by 200 microns in size.
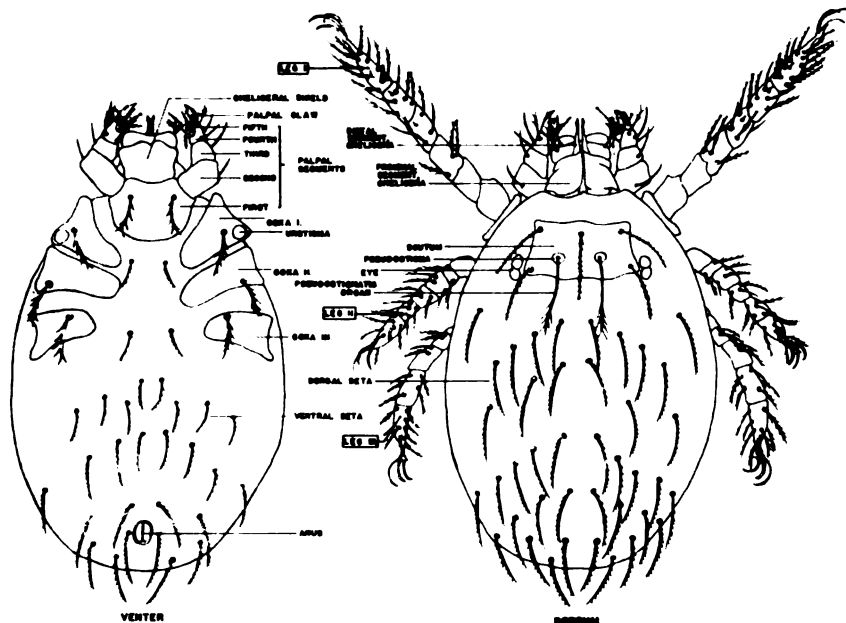
Figure 36
Dorsal and ventral views of Trombicula akamushi

The characteristics of the terrain in which mites are prevalent vary with the geographic location. The area may be swampy, bush-covered ground along jungle margins or shaded and grass-covered along streams. Atoll islands without much grass have been involved. In general, mite-infested areas are shaded and have a high humidity. Natives frequently know the location of infested areas, and their aid should be enlisted in identifying them.

PLATE VIII.

OTHER MITES OF MEDICAL IMPORTANCE

Dorsal small, red, pear-shaped 0.6 to 0.9 mm. long   Ventral   Dorsal   Ventral
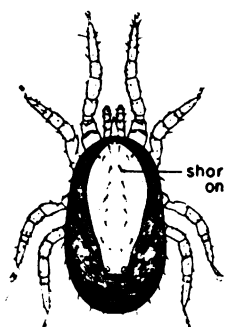
short hairs on scutum
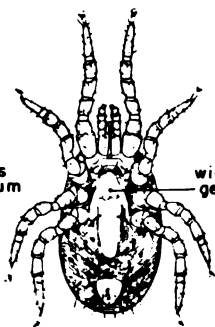
wide genito-ventral plate

Dermanyssus gallinae
(chicken mite)
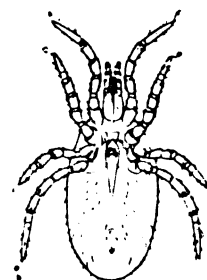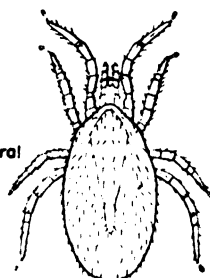
Ornithonyssus bacoti
(tropical rat mite)

DERMANYSSIDAE

small bulbous organ arising between legs 1 & 2
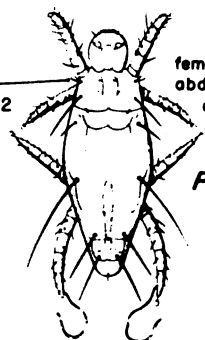
female before abdomen has become distended with eggs

Pyemotes ventricosus
(grain itch mite)
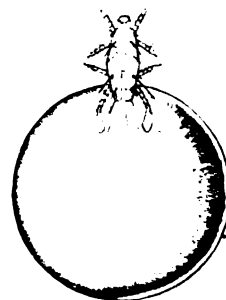
gravid female

PYEMOTIDAE = (PEDICULOIDIDAE)
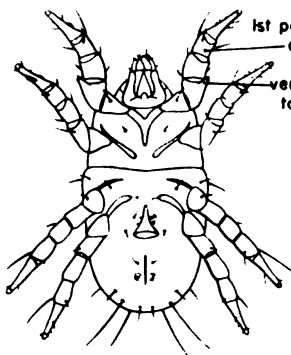
1st pair legs enlarged

ventral tooth-like spur
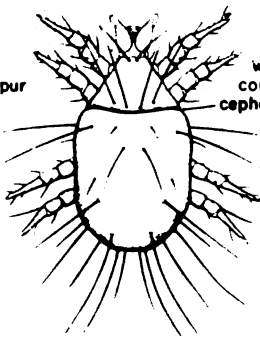
well marked constriction between cephalo thorax & body

legs reduced to stumps

abdomen vermiform

Acarus siro
(flour mite)

Tyrophagus longior
(copra itch mite)

Demodex folliculorum
(hair follicle mite)

ACARIDAE (=TYROGLYPHIDAE)   DEMODICIDAE

58

Various field rodents (including rats and mice), birds, bandicoots, lizards, and snakes are the natural hosts for larval mites. Some of these may also serve as the natural reservoirs of the tsutsugamushi rickettsia, although evidence of this is not conclusive. When the parasitic larval mites feed on an infected host, they pick up the infection and retain it through their free-living nymphal and adult stages. The infection is passed on to the next generation of mites through the eggs. It is this resultant second generation of larval mites that bites man and transmits the disease.

During the Korean War it was found that the epidemiology of epidemic hemorrhagic fever and the activity of certain trombiculid mites was so similar that control of trombiculid mites was recommended and used in the control of this disease.

Lelapitidae. The important mite of this family is Lelaps jettmari Vitzhum which is a parasite of rodents in Manchuria, Korea, and Japan. In Manchuria, a virus recovered from mites of this species on rodents was presumed to be the causative agent of epidemic hemorrhagic fever. Lelaps jettmari is therefore now believed to be the natural vector of the disease.

Dermanyssidae (Plate VIII). There are three genera of medical importance in this family: Ornithonyssus, Dermanyssus, and Allodermanyssus.

The tropical rat mite, Ornithonyssus bacoti (Hirst) is found in the United States and in warm and temperate climates throughout the world. Its normal host is the rat, but it will readily attack man in areas where rats are numerous, such as in warehouses, stockyards and granaries. The cycle from egg to adult requires around 14 days, the adults living about three months. The bite of this mite is accompanied by an intense itching sensation, and is followed by hemorrhagic areas. Experimentally, the tropical rat mite has been found capable of transmitting endemic typhus, and rickettsial pox.

The northern fowl mite, Ornithonyssus sylviarum (C. & F.), which is parasitic on fowls and birds, readily attacks man. It harbors the virus of Western equine encephalomyelitis, and a virus of chickens known as Newcastle disease. The life cycle is believed to require from eight to ten days. The northern fowl mite is widespread among birds and is cosmopolitan in distribution.

The chicken mite, Dermanyssus gallinae (DeGeer), is a parasite of chickens, turkeys, pigeons and other wild birds throughout the world, occasionally biting man causing skin lesions and itching. The cycle from egg to adult may be completed in as little as seven days depending upon the temperature.

A mouse mite, Allodermanyssus sanguineus (Hirst), parasitic on mice and rats, is found in the United States and in several locations in the Eastern Hemisphere. It is the natural vector of rickettsialpox of man. The reservoir of the disease is the house mouse.

Pyemotidae (Pediculoididae) (Plate VIII). This family includes species that are predaceous on insects affecting grain crops. The grain itch mite, Pyemotes ventricosus (Newport), feeds on the larvae of such insects as the grain moth, wheat jointworm, bean and pea weevils, and the cotton boll weevil. It readily attacks man resulting in a dermatitis called "straw itch" which superficially resembles chickenpox, smallpox, or scabies and is often accompanied by an elevation in temperature and sweating. The itching may last for several weeks. Infection is obtained by sleeping on straw mattresses or from laboring in grain fields.

Acaridae (Tyroglyphidae) (Plate VIII). Mites in this group infest stored products such as dried fruits, cereals, grains, beans and other food stuffs. They are very minute, and in a certain stage (hypopial) they may be carried on the bodies of insects and thus gain dissemination. They cause dermatitis in man that may be mistaken for straw itch or scabies. Several species are implicated: Tyrophagus longior var. castelanii (Hirst) causes "copra itch", Acarus siro Linn. is the cause among vanilla pod workers of a dermatitis called "vanillism" and Glycyphagus domesticus (DeGeer). is responsible for "grocers itch".

Demodicidae (Plate VIII). The hair-follicle mites are found parasitizing the hair follicles and sebaceous glands of man and animals. They are elongate with very short legs, and have piercing mouth parts. Demodex folliculorum Simon attacks man, living down deep in the hair follicles and sebaceous glands. It spends its complete cycle on the host causing a mild pruritus and a fibrous area around the mites, together with a burning sensation. The mite is common, but usually its presence passes unnoticed by the infected individual.

60

CLASS INSECTA
(insects)

General Characteristics

Without question, insects are the most important of all arthropods from the standpoint of human disease. They are, therefore, studied in greater detail here than any of the foregoing arthropod classes. The members of the Class INSECTA have the body divided into three regions -- head, thorax, and abdomen. They have three pairs of legs and one pair of antennae (Fig. 37).

External Anatomy

The grasshopper, because of its large size, illustrates well the features of the Phylum Arthropoda. The body is segmented and its parts are arranged equally along both sides of a plane dividing the body into lateral halves (bilateral symmetry), the "skin" is hard and serves as an exoskeleton, and the appendages (antennae, mouth parts, legs) are jointed.

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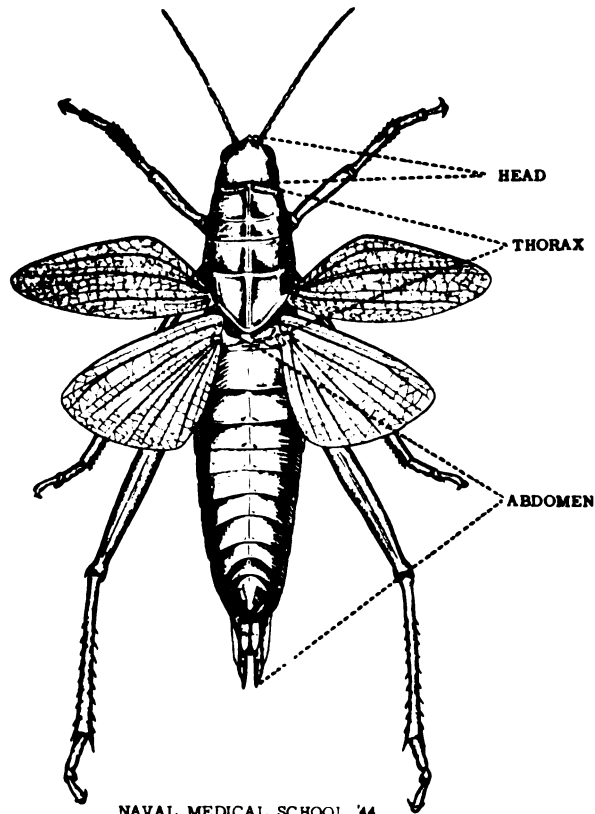
Figure 37
Dorsal view of a grasshopper

61

Insects may be very large, such as butterflies and certain rhinoceros-beetles, or barely visible to the eye as in certain species of wasps. Size, shape, color and the number of body segments are characters often used in insect identification.

The exoskeleton, or outer framework of insects that protects the internal organs, is armor-like consisting of a cuticle of chitin, proteins, waxes and other substances produced by the inner epidermis which makes it hard, and restricts its permeability. This body wall protects the insect from evaporation, its enemies, and disease. It also acts as a substantial area for the attachment of the muscles of the legs, wings and other movable portions. It contains sensory hairs and other processes for the reception of external stimuli. This exoskeleton will not stretch, bend or allow for the expansion necessary for the daily life processes, so these hardened body areas consist of plates separated by soft, membranous areas which permit movement, and the expansion necessary in feeding and egg development. Growth expansion of immature forms is permitted by periodic shedding of the chitinous cuticle (molting or ecdysis) discussed later under "growth."

Further study of the grasshopper reveals that the body segments of an insect are grouped into three main regions, head, thorax and abdomen (Plate IXA). This differs from the previously discussed Class Arachnida which had the body divided into only one or two regions (ticks, mites, spiders, scorpions and others).

The Head. Conspicuous structures on the head are: (1) the two antennae or "feelers," (2) the two large compound eyes and the simple eyes or ocelli, and (3) the mouth parts, in the case of the grasshopper of the chewing type (Plate IXB and C).

Antennae: The antennae are two in number and sensory in function. They are located toward the front of the head, and are of varied forms often aiding in insect identification (Fig. 38).

Eyes: The large compound eyes are made up of many hexagonal facets or lenses enabling the insects to see in several directions at the same time. The ocelli are three simple eyes each with a single lens, located usually between the compound eyes in the adult, often in the form of a triangle. The immature forms have simple eyes only, which are often located in clusters.

Mouthparts: The most important way in which insects inflict damage as vectors of human disease is through their feeding or eating habits. Since insects feed in a variety of ways, it becomes evident that a knowledge of insect mouth parts is of prime importance in any study of insect transmission of disease.

Mouth parts of medically important insects may be classified as follows (Fig. 39):
1. Chewing mouth parts: Although chewing insects are not involved in the transmission of diseases to the extent found in the sucking forms, they do illustrate

62

PLATE IX.

THE ANATOMY OF THE GRASSHOPPER

Head   Thorax   Abdomen

antenna

eye

tympanum

ovipositor

cercus

coxa

trochanter

spiracles

femur

tarsus

tibia
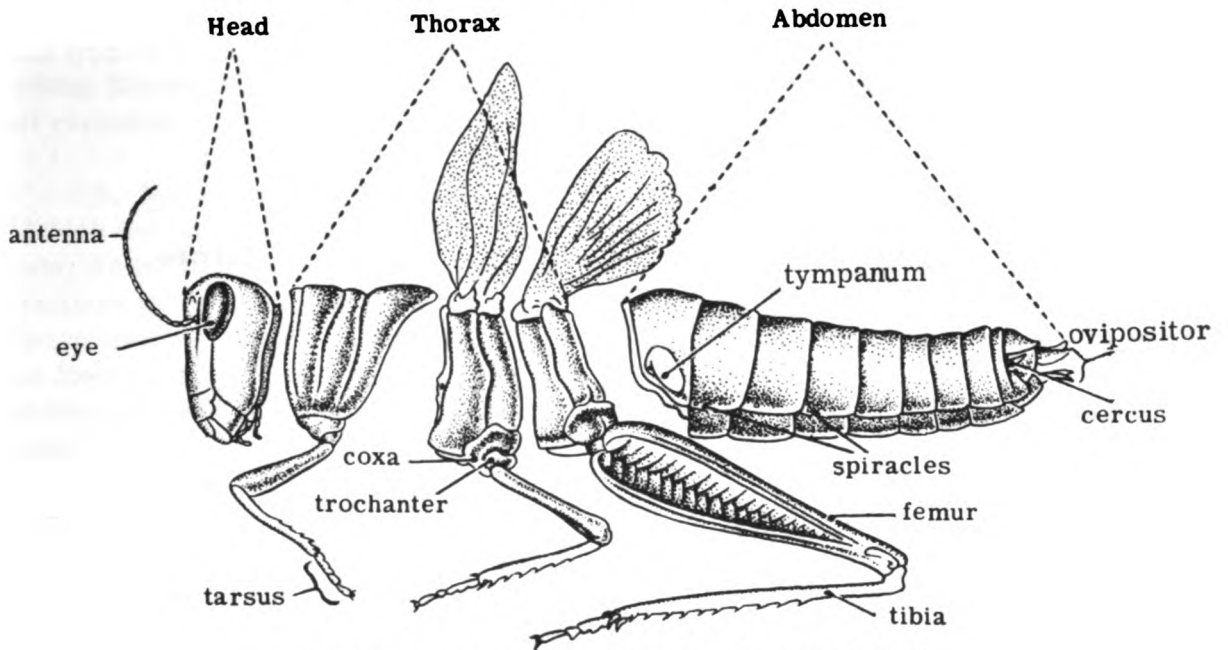
A. Lateral view of a grasshopper (disarticulated)

ocelli

labrum

mandible

hypopharynx

maxilla

maxillary palpus

labrum

labium

labial palpus

Frontal   Lateral
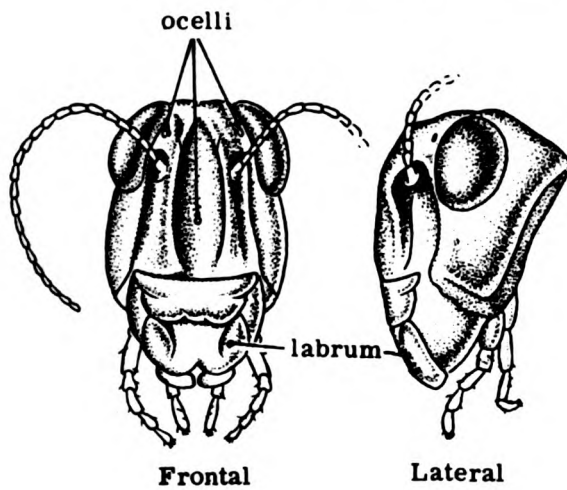
B. Head
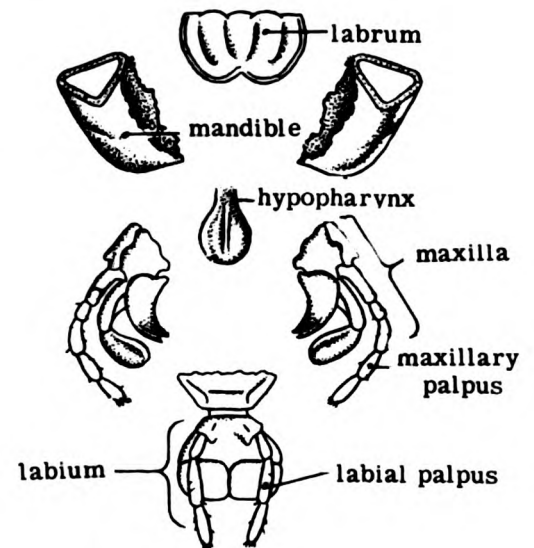
C. Mouth parts (chewing type)

63
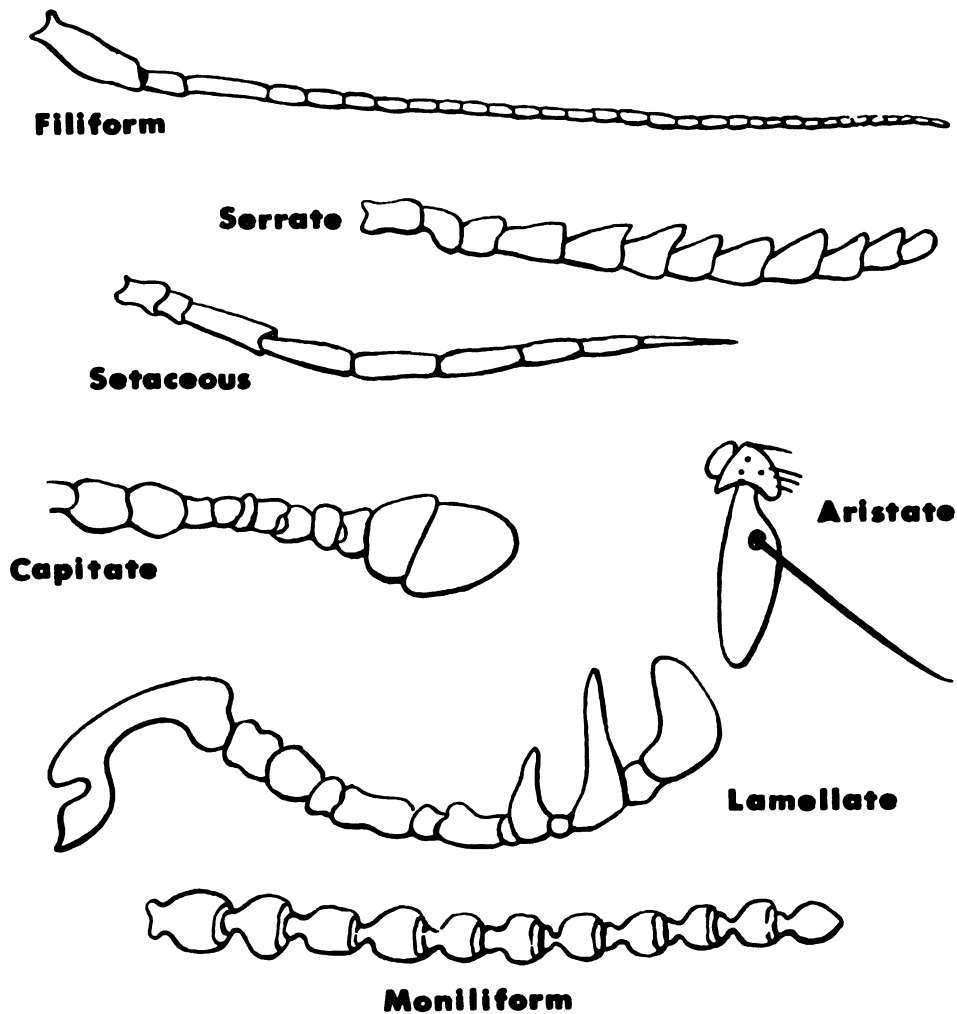
Figure 38
Types of insect antennae*

the primitive type of mouth parts from which all other more specialized types have developed. Some of them are associated with the mechanical transmission of disease agents (Hymenolepis diminuta (Rudolphi), Moniliformis moniliformis (Bremser) and in one instance, at least, a chewing insect (flea larva) is involved in the biological transmission of the dog tapeworm Dipylidium caninum (Linn.).

Insect mouth parts consist of a labrum or upper lip, two mandibles for cutting off food products and grinding them, a tongue-like hypopharynx, maxillary and labial palps attached to the maxilla and labium respectively which are thought to be for taste, smell, and touch, and the labium which is the lower lip (Plate IXC; Fig. 39A). Beetles and cockroaches are examples of insects with chewing mouth parts.

* After D. H. E. W. - PHS, CDC. Atlanta, Georgia

2. <u>Sucking mouth parts</u>: In the more specialized type of mouth parts discussed below, the same basic parts of the chewing type have been greatly modified to form organs for the ingestion of liquids.

a. <u>Biting</u>: This type of mouth parts is characterized by a tubular beak, or <u>proboscis</u>, enclosing several needlelike pieces known as stylets (<u>mandibles, maxillae, hypopharynx, and labrum</u>) (Fig. 39 B.). The outer tube or proboscis is the modified <u>labium</u> which is usually a protective, sheathlike structure for holding the other parts. This type is found in the Hemiptera, Anoplura, Siphonaptera, and most of the blood sucking Diptera. All of these orders include insects which transmit disease agents that circulate in the blood of man.

b. <u>Non-biting</u>: The term lapping or sponging is sometimes applied to this type of which the house fly is a good example (Fig. 39 C.). They are only able to eat liquid foods, or foods they can readily dissolve. There are no mandibles or maxillae, but the maxillary palps are retained as sense organs. A tube is formed by the labium and the labrum which is tipped by a spongy organ, the labellum. Liquid foods are obtained via this food channel as they are picked up by the labellum. Hard foods that are easily soluble are first dissolved by a drop of regurgitated saliva and then taken in as a liquid.
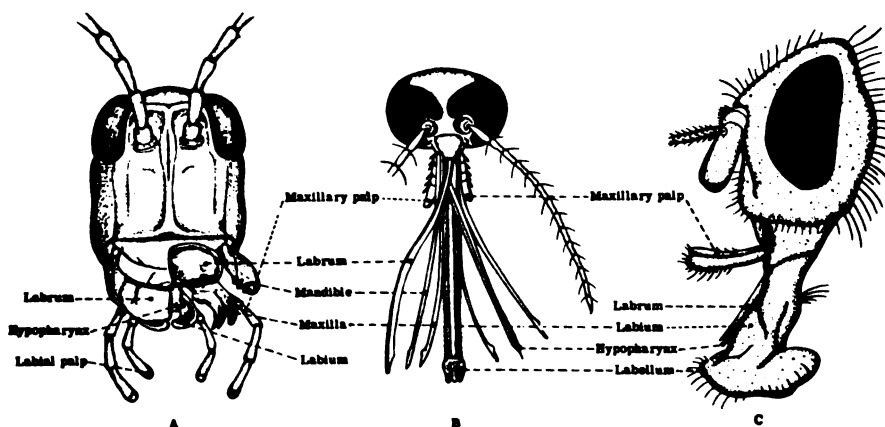
<u>Figure 39</u>
Types of mouth parts: A. Primitive chewing mouth parts.
B. Mouth parts modified for biting. C. Mouth parts modi-
fied for lapping or sponging.

The mouth parts of insects have a very practical bearing on the type of insecticide to be used in their control. Those insects with chewing mouth parts or those with sponging or lapping, may be controlled with <u>stomach poisons</u>, while those with piercing-sucking mouth parts cannot usually be controlled by poisoning their food. Against these forms, <u>contact insecticides or fumigants</u> should be used.

65

Thorax: The second body region, the thorax, is made up of three segments, the prothorax, mesothorax, and metathorax. Each segment bears a pair of legs, and in the winged forms the last two segments each a pair of wings. (In Diptera the meta-thoracic wings have been reduced to halteres).

Legs: The legs are of various types and each is divided (from the body out-ward) into a coxa, trochanter, femur, tibia, tarsus, and pretarsus (Plate X). They are of value for identification purposes.

Wings: The wings are membranous outgrowths of the body wall, strengthened by ribs or veins which form patterns called venation. The veins running from the body toward the tip of the wing are called longitudinal veins, while those running crosswise of the wing connecting the longitudinal veins are called cross veins. Wing venation is a valuable tool in taxonomic keys, the veins being given names and numbers (Fig. 40).
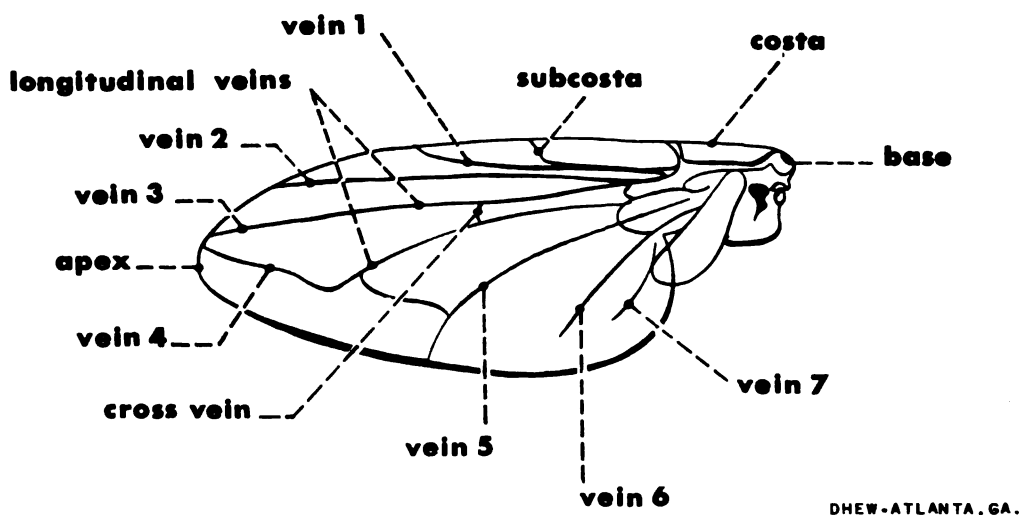
Figure 40.
Wing venation of a fly

Abdomen: The abdomen of an insect is made up of a series of segments which, except for the very last ones, are similar in shape. It usually consists of 10 or 11 segments, although this number may be greatly reduced as in the Collembola which has only six. The last few segments may be modified into copulatory structures, or an ovipositor for depositing eggs.

Internal Anatomy

The internal anatomy of an insect involves primarily the organs that carry on the body functions of respiration, circulation, digestion, excretion, nerve conduction, and reproduction.

PLATE X.
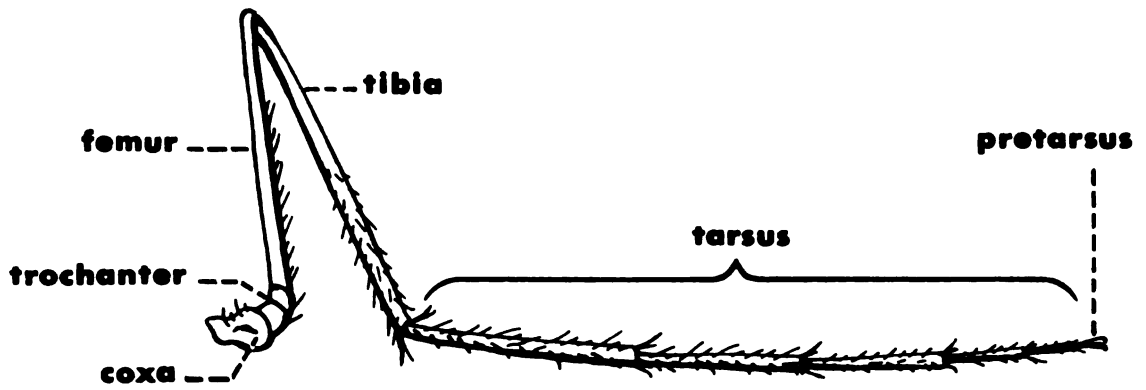
A. Walking
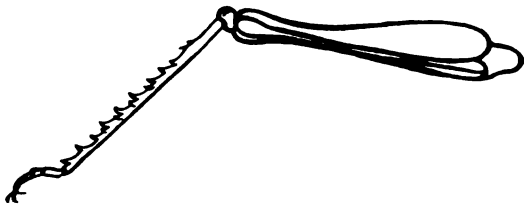
B. Jumping
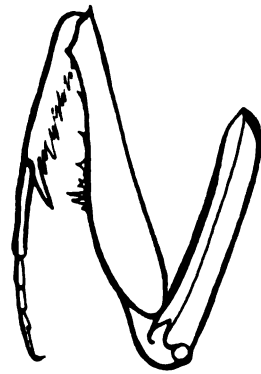
C. Grasping
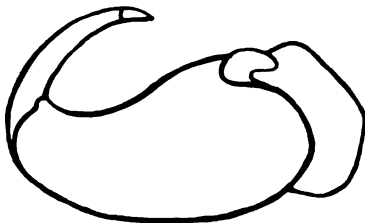
D. Clasping

E. Digging

DHEW-ATLANTA,GA.

Primary Organs

Respiratory system: In the majority of animals, oxygen supply is a function of the blood stream. In insects, the respiratory system consists essentially of a network of internal air tubes (tracheae) which communicate with the outer air through small openings (spiracles) in the body wall and supply the individual tissue cells with air through a multiplicity of branches and microscopic tubules (tracheoles) (Fig. 41). The location of the spiracles varies from the type with ten pairs (a pair on each of the last two thoracic segments and on each of the first eight abdominal segments) to the mosquito larva, having them only on the eighth abdominal segment. Contraction and expansion of the body volume crushes or dilates the tracheae, forcing the air in and out, thus assisting in the rapid ventilation of the tracheae. In some other arthropods, gills (as in crustaceans) or "book lungs" (as in some spiders) may serve the functions of respiration in place of tracheae and tracheoles.

Circulatory system: The dorsal vessel or "heart" extends the length of the body just below the body wall from the end of the abdomen into the head region. Actually, the dorsal vessel is divided into two portions, the posterior portion, which pulsates, being called the heart, and the anterior tube which carries the blood from the heart into the head area, called the aorta. The dorsal vessel is so constructed that on diastole, blood is drawn in from the surrounding body space (haemocoele) through minute valvular openings (ostia) in the side of the heart, typically a pair in each of the first nine segments of the abdomen; and on systole, this blood is squirted forward to bathe the brain, trickle down and back into the haemocoele (Fig. 42).

The insect's circulatory system is described as "open," because only in its brief passage through the dorsal vessel is the blood confined within the walls of a tube. The rest of the time it lies free in the haemocoele, where it bathes all the tissues, supplying them with food and removing the waste products.
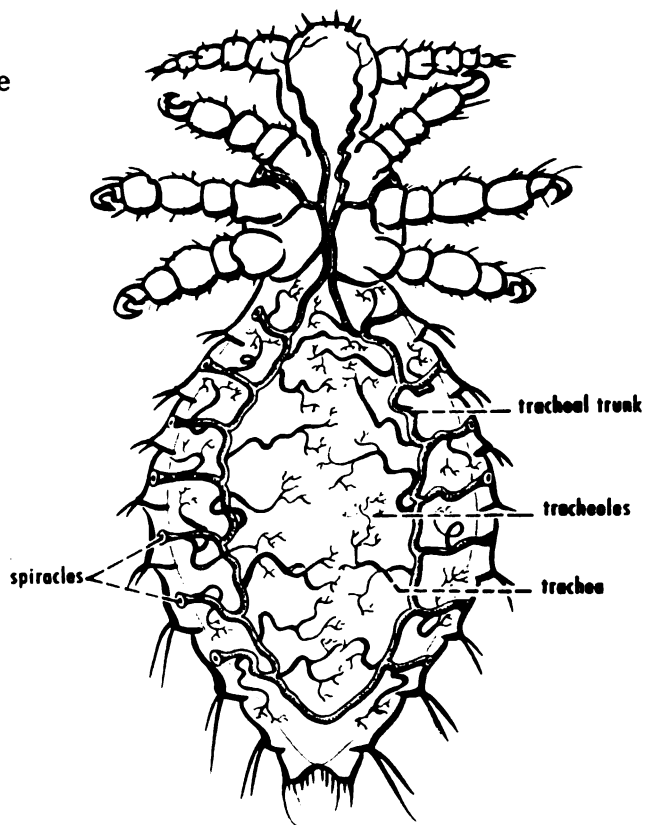
Figure 41
Portion of the respiratory system of a louse. *

* After D. H. E. W. - PHS, CDC, Atlanta, Ga.

Accessory structures that assist the dorsal vessel in circulating the blood are the delicate, undulating sheets of muscles called the dorsal and ventral diaphragms and the auxiliary contractile vessels sometimes located at the bases of the legs, antennae, and wings.
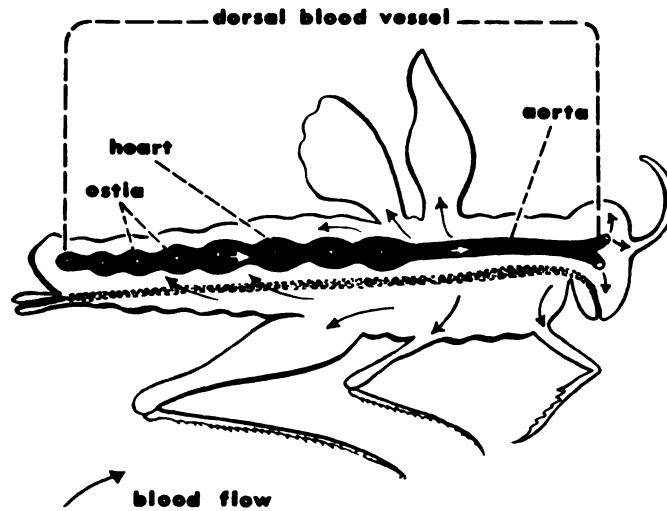
Figure 42
Circulatory system (diagrammatic)*

The blood of an insect is composed of a liquid haemolymph and nucleated haemocytes. It carries no oxygen, but transports dissolved food to the tissues and removes the waste products.

In some of the other arthropods, i.e., some of the crustaceans and arachnids, an elaborate system of blood vessels may branch out from the dorsal vessel.

Digestive system: The digestive system of an insect is essentially a tube running through the central part of the body (Fig. 43). The food, which may consist of other insects, blood, leaves or plant juices, passes through the mouth, where if there are salivary glands, enzymes are provided; continues to the crop which is an enlarged portion utilized for storage; then to the proventriculus or gizzard if present, where it is further macerated. It is mixed with the digestive enzymes and micro-organisms from the gastric caeca in some insects, and digested by secretions of the mid-gut (stomach), where absorption also takes place. The mid-gut is the only part of the alimentary canal that is not lined with an impermeable cuticula, the fore and hind guts being embryonic invaginations of the ectoderm. The unabsorbed residue then passes back into the hind-gut (intestine) where it is joined by the metabolic wastes emptied from the malpighian tubules (which function as kidneys in insects) and passes on out through the anus.

* After D.H.E.W. - PHS, CDC, Atlanta, Ga.
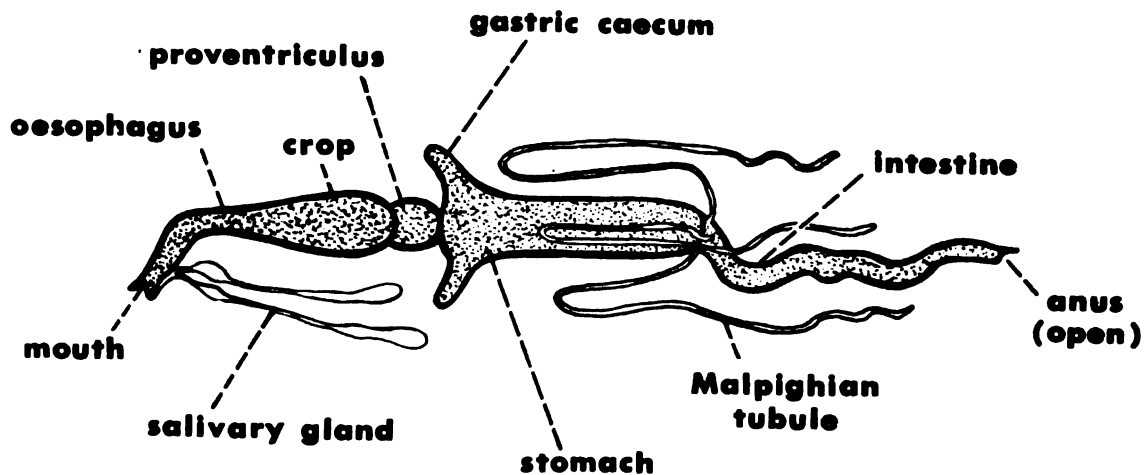
Figure 43
Digestive and excretory systems of an insect (diagrammatic)*

In many arthropods, the mouth parts and the alimentary canal are greatly modified. These modifications are correlated with specialized habits.

Excretory system: The blood and the Malpighian tubules function in the excretion of waste from the cells of the body. The waste products are absorbed from the cells by the blood, and in turn extracted from the blood by the Malpighian tubules which ultimately discharge them into the intestine.

Nervous system: The nervous system of insects includes the following: a complex neural mass, called the "brain," located above the oesophagus in the dorsal part of the head; an almost equally complex "sub-brain" on the floor of the head connected to the brain by two nerve cords encircling the esophagus; and a chain of paired ventral ganglia lying beneath the alimentary canal connected by a double cord extending backward along the ventral surface of the thorax and abdomen (Fig. 44). Normally the thorax has a thoracic ganglion or nerve center in each segment, which is also true of the abdomen, but in various higher groups, the ganglia may have fused in the thorax into one larger mass, and become so small in the abdomen as to be almost indistinguishable. These nerves and certain autonomic nerves connected with this system innervate the various organs and muscles of the body, and associate the stimuli received from the various sensory receptors. Insects are provided with organs of varying efficiency for seeing, tasting, smelling, and hearing.

* After D.H.E.W. - PHS, CDC, Atlanta, Ga.

70
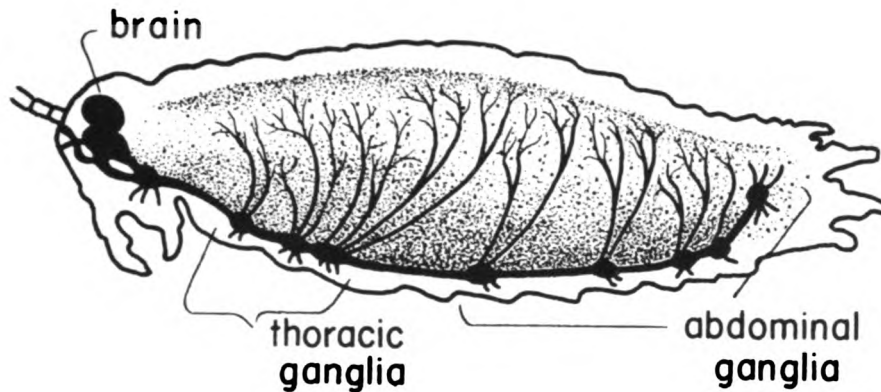
Figure 44
Diagram of the central nervous system of a grasshopper

Reproductive systems: Male and female reproductive systems in insects are structurally similar, but the sexes are distinct. Eggs are produced in the paired ovaries of the female. They pass down the paired oviducts into a common duct, or vagina, where they are fertilized by sperm stored in accessory pouches, the spermatheca, and the bursa copulatrix (Fig. 45 B). This storage of sperm in the female is important because it permits the female to lay fertile eggs continuously, even though copulation may be very infrequent or occur only once. Some have accessory glands for the secretion of an adhesive substance for the eggs. In the honey bee, the females can produce infertile eggs which develop into drone bees while the fertile ones produce the workers and queens. Insects that lay eggs are said to be oviparous, while those that give birth to living young are called vivparous. In addition, parthenogenetic reproduction (without fertilization) occurs.

In the male, spermatozoa are produced in paired testes, pass down the vas deferens, and are stored in the seminal vesicle until required. At this time they receive a liquid vehicular substance from the accessory glands, pass into the ejaculatory duct and out of the body (Fig. 45A).

Both sexes have secondary sex structures attached to the terminal segments of the abdomen, which serve as claspers in the male, and as ovipositors in the female.

Insect Development - Metamorphosis

It is important to recognize that most insects undergo marked changes in size, form, and stucture during their development from egg to adult. This type of change during the life cycle of an insect is termed metamorphosis and may occur in several ways.

71
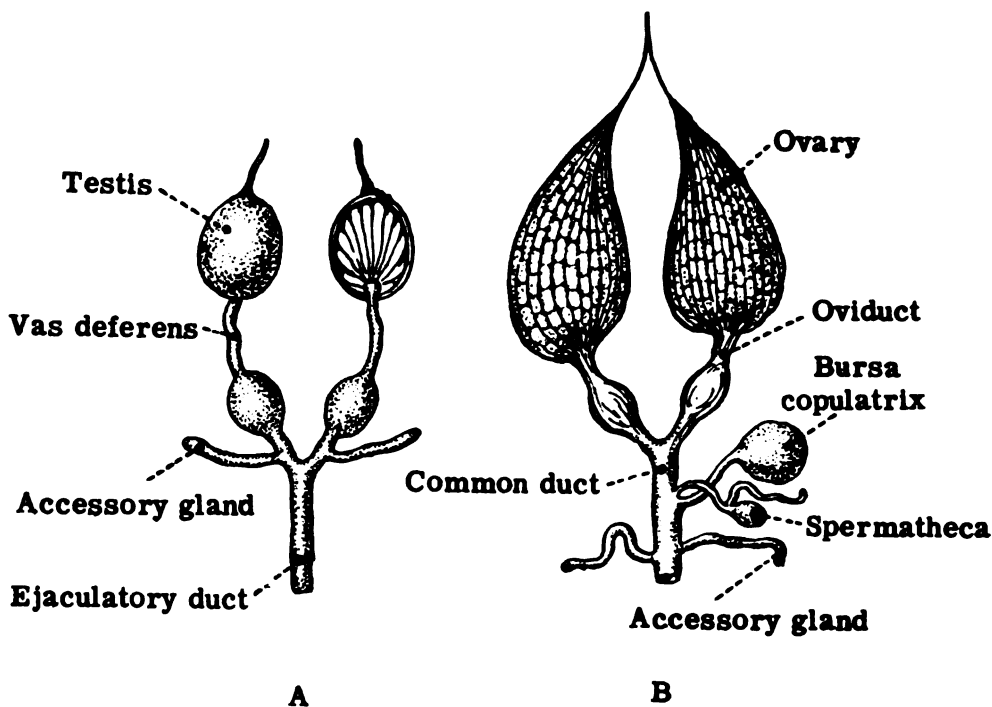
Figure 45
Diagram of the reproductive organs of a grasshopper. A. Male. B. Female

Since control measures may be directed against several stages in the life cycle
of an insect, it is important to associate the immature and adult stages even though
they may differ greatly in appearance. Thus a knowledge of the types of metamor-
phosis and an ability to recognize various immature stages are of practical importance
in the control of insect-borne diseases. In many instances, species identification can
be as readily accomplished by examining immature forms as by examining adults.

Important Types of Development (Plate XI)

Without Metamorphosis (ametabola - without change): In a few small groups
of insects, the young as they hatch from the egg resemble the adult very closely, ex-
cept for size. Since there is little or no change in form during their development,
these insects are described as having no metamorphosis. This type of development
is characteristic of the silverfish (THYSANURA) and the springtails (COLLEMBOLA)
which are primitively wingless, and have young that differ from the adults only in size
and in the development of the reproductive organs. The lice also develop without meta-
morphosis, but they are believed to have winged ancestors, and to have acquired the
ametabolous development through their parasitic habits.

Gradual Metamorphosis (paurometabola - with gradual change): In the more
primitive insects that develop wings, wing-pads appear in the young after about the

72

PLATE XI.

INSECT DEVELOPMENT

(hair)   Eggs or "nits"   (clothing)   IMMATURE STAGES   ADULT

WITHOUT METAMORPHOSIS
(lice)

EGGS   rudimentary wings   rudimentary wings   wings fully developed

NYMPHS   ADULT
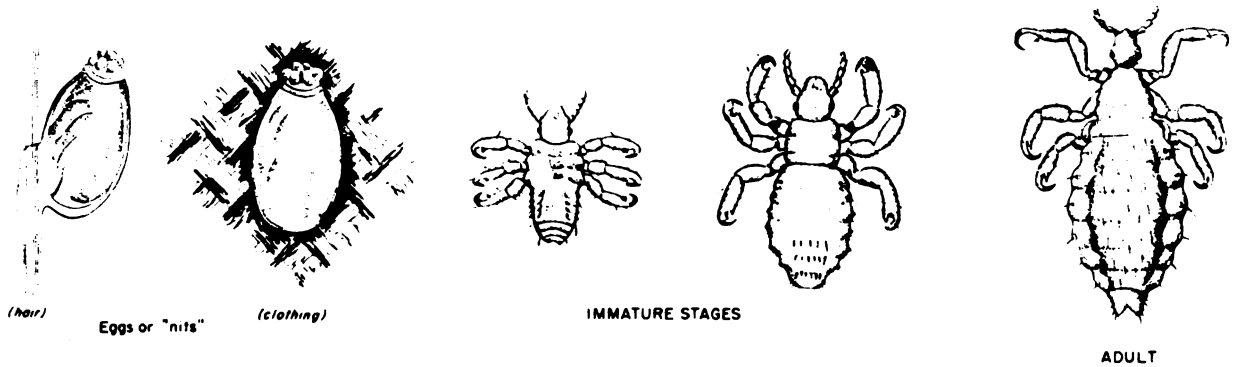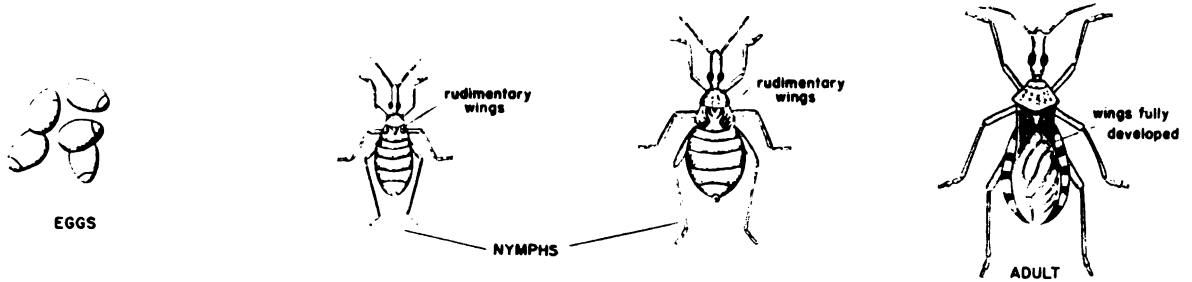
GRADUAL METAMORPHOSIS
(assassin bugs, bed bugs)

EGGS   LARVA   PUPA   ADULT
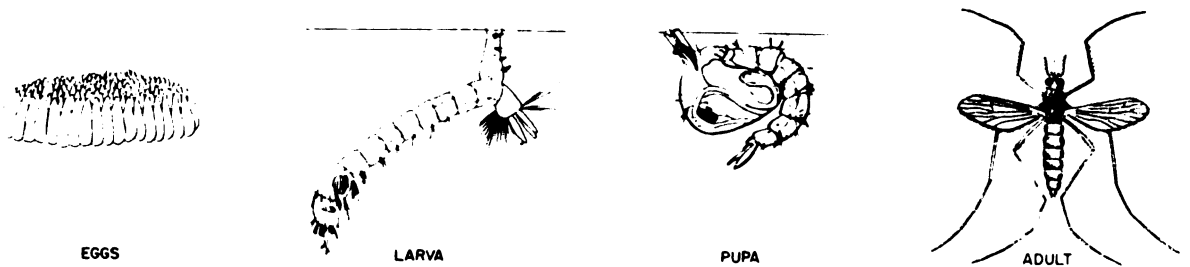
COMPLETE METAMORPHOSIS
(mosquitoes, flies, fleas)

second molt, and increase gradually in size as the insects develop. During the last stage of development, all the adult structures are formed, and the adult emerges from this stage rather than from a pupa as in the holometabola. The young are therefore very similar to the adults, except for size and the possession of wing-pads which become increasingly larger with successive molts, making them appear more and more like the adults as they develop. This type of development is termed gradual metamorphosis, since the change to the adult form is a gradual one.

The young of insects with this type of metamorphosis are called nymphs and are sexually immature. They commonly have the same feeding habits as their parents and are frequently found together in the same situations. Control measures are thus the same for both adults and immature stages. Many important insect orders have this type of development, including the HEMIPTERA, some of which are medically important.

Complete Metamorphosis (holometabola - with complete change): Insects with complete metamorphosis have developmental stages that are very different from each other. A complete change in appearance is involved in their development from egg to adult. In many of these insects, the mouth parts of the immature and adult forms are of totally different types, and the insects themselves may have entirely different feeding habits and live in different habitats. Hence, control measures applied against adults and immature insects may differ greatly in those groups undergoing complete metamorphosis.

In these forms, the eggs hatch into larvae (singular, larva) which are feeding forms. These larvae may live in soil, in water, or even develop as parasites in various animals. During their development, the larvae grow and molt a number of times; but in no case do the wings appear as external pads as they do in the nymphs of insects undergoing gradual metamorphosis. Once growth and larval development are completed, a striking change takes place as the larva transforms into the pupal stage. The pupa (plural, pupae) is a nonfeeding stage in which a reorganization of structure to the adult form takes place. Once this transformation is completed, the mature or adult insect emerges from the pupal case. Among the many important orders having this type of metamorphosis are the DIPTERA (mosquitoes and flies), SIPHONAPTERA (fleas), LEPIDOPTERA (moths and butterflies), HYMENOPTERA (ants, bees, and wasps), and the COLEOPTERA (beetles).

Hypermetamorphosis: In this type of development there are two or more larval instars that differ in shape and habits. Examples of this type of development are found among the parasitic rove beetles, COLEOPTERA (Staphylinidae), which are active and slender in the first instar, and grublike in all other immature stages; and some of the caddisflies (TRICHOPTERA) which have slender, free-living larvae in the first instar that develop into stouter larvae that construct cases in which to live.

74

The Growth of Insects

The chitinous exoskeleton of insects has already been mentioned. It protects the organism from evaporation of water vapor by a waterproof covering, as well as furnishes a solid framework for protection, and for the attachment of muscles. This covering hampers the growth of the immature forms and requires a molting process by which it may be discarded along with the lining of the respiratory system, and the fore and hind intestines which are ingrowths of this body wall. To aid in this molting process, a molting fluid is secreted between the horny outer covering (old cuticula) and the new soft cuticula that has been secreted by the hypodermal cells. This disolves the inner portion of the old cuticle, loosening it, but does not affect the new layer beneath. The body is distended by swallowing air or water, causing the old cuticle to rupture along the dorsal surface (in most cases). The insect then frees itself by working its way out of the old cuticle through the rupture. The new cuticle allows for expansion, then hardens and resumes its normal color. This process of molting only occurs during the immature stages of the insect. There are not a great number of molts normally, but the number is usually constant for a species.

The Mature Insect

The adult insects emerging from pupae are not necessarily sexually mature. Normally this requires a period of time for both males and females. If mating occurs before the eggs of the female are mature, the sperm is stored in the female spermatheca until the time of oviposition. Some of the insects reproduce without mating (parthenogenesis), but most of them lay eggs following copulation. The eggs vary in shape, and the shell may be reticulate, ribbed or sculptured. They may be laid singly, or in clusters, some are encased in capsules (cockroach), in froth, glued to leaves, dropped on the ground, or placed within a leaf or stem.

Some insects are viviparous, giving birth to living young instead of laying eggs. The eggs hatch within the insect's body prior to larvaposition. This happens among the flesh flies of the Order Diptera. A few insects have uterine development of the larvae wherein glands produce nourishment for the larvae until maturity within the female, pupation taking place soon after larvaposition.

The life of the adult insect may be very short as in the aphid which lives four or five days, or very long as in the social insects. The queen termite of some species may live well over fifteen years.

Key to the Orders of Insects of Medical Importance

1. Wings present 2

   Wings absent 10

2. Two wings 3

   Four wings 4

3. Abdomen with two or three long, slender, threadlike caudal processes.
   Mouth parts degenerate or wanting. Without halteres (clubbed appen-
   dages in place of second pair of wings). . . . . (Mayflies) <u>Ephemeroptera</u>

   Abdomen without long, slender, caudal appendages. Mouth parts
   sucking. Halteres present . . . . (Flies, mosquitoes) <u>Diptera</u>

4. Front and hind wings dissimilar in texture 5

   Front and hind wings similar in texture 7

5. Bases of front wings thickened, leathery; distal portions membranous
   and usually overlapping; mouth parts piercing sucking . . . . (True bugs) <u>Hemiptera</u>

   Bases of front wings of same texture as distal portions,
   Mouth parts chewing 6

6. Front wings horny, stiff, veinless, utilized as elytra (wing covers).
   Elytra meeting in straight line down the back, and covering the ab-
   domen. Hind wings membranous, folded back under wing covers
   when at rest . . . . (Beetles) <u>Coleoptera</u>

   Front wings thickened, leathery, flexible, distinctly veined. Hind
   wings thin, larger than front wings, folded lengthwise and fan-like
   when at rest . . . . (Grasshoppers, cockroaches etc.) <u>Orthoptera</u>

7. Wings proportionately large, both pairs covered above and below
   with scales, usually of various colors. Mouth parts, sucking, coiled
   when at rest, or mouth parts wanting . . . . (Moths, butterflies) <u>Lepidoptera</u>

   Wings proportionately small, without scales, transparent or hairy 8

8. Wings with many longitudinal veins and cross veins (net-like),
   triangular, hind pair much smaller than front pair or absent.
   Abdomen with filamentous caudal processes. Mouth parts vestigial.
   Antennae no longer than head . . . . (Mayflies) <u>Ephemeroptera</u>

   Wing venation reduced with few cross veins, or veinless.
   Antennae longer than head 9

9. Wings membranous, usually thickly covered with long, fine, hairs; hind wings normally broader and shorter than front wings; wings held roof-like over body at rest. Mouth parts vestigial, body soft.. (Caddisflies) Trichoptera

Wings membranous, transparent, naked. Hind wings smaller than front wings, and often fastened to front wings by rows of hooks. Wings not held roof-like over body at rest. Mouth parts chewing or chewing lapping. Body hard. Tip of abdomen often with sting, piercer or saw.............. (Wasps, bees, and ants) Hymenoptera

10. Abdomen with a maximum of six segments, ventral sucker on first segment, forked spring on fourth, and a pair of appendages, the catch, on the third. Chewing mouth parts. Small insects, non parasitic .... (Springtails) Collembola

Abdomen with more than six segments 11

11. Body bilaterally compressed. Jumping legs. Piercing-sucking mouth parts. Small, parasitic insects .... (Fleas) Siphonaptera

Body not bilaterally compressed. Walking legs 12

12. With chewing or chewing-lapping mouth parts 13

With piercing-sucking mouth parts, body flattened dorso-ventrally 14

13. With chewing mouth parts. Body small, flattened dorso-ventrally. Broad, rounded head. Tarsi one or two segmented with one or two claws. Parasitic, mostly on birds .... (Chewing lice) Mallophaga

With chewing or chewing-lapping mouth parts. Body not flattened. Abdomen joined by a pedicel. ....
...................(Wingless worker ants, and female velvet ants) Hymenoptera

14. Mouth parts retractile. Head narrow and pointed. Tarsi one segmented with single claw adapted for clinging to hairs. Parasitic on mammals .... (Sucking lice) Anoplura

Mouth parts not retractile, three segmented beak held under head between forelegs when at rest. Antennae four segmented. Tarsi three segmented with two claws which are not adapted for cling- ing to hairs. Parasitic on man and chickens .... (Bed bugs) Hemiptera

PLATE XII.

CLASS INSECTA
ORDERS OF MEDICAL IMPORTANCE

DIPTERA (flies)

one pair wings..
one pair halteres.
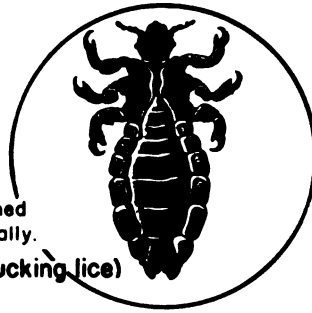
wingless
body flattened
dorso-ventrally.

ANOPLURA (sucking lice)
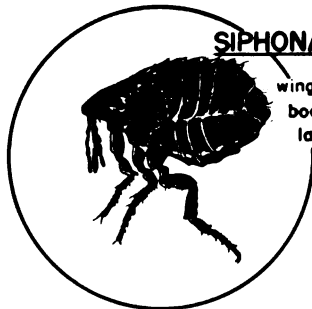
SIPHONAPTERA (fleas)

wingless..
body flattened
laterally.
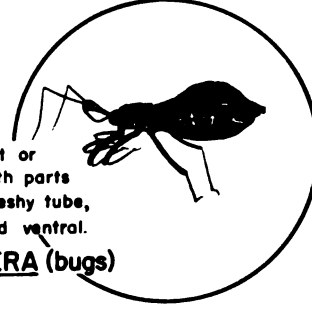
wings present or
absent.. mouth parts
appear as fleshy tube,
recurved and ventral.

HEMIPTERA (bugs)
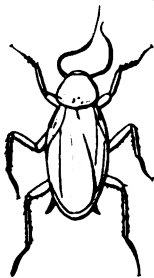
**ORTHOPTERA
(cockroaches)**

**LEPIDOPTERA
(butterflies)**

**COLEOPTERA
(beetles)**

**HYMENOPTERA
(bees, ants)**
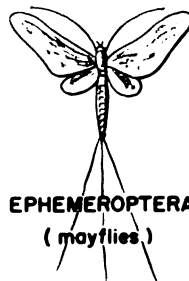
**EPHEMEROPTERA
(mayflies)**

**COLLEMBOLA
(springtails)**
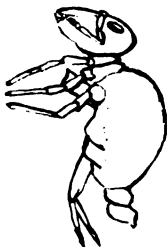
**MALLOPHAGA
(biting lice)**

**TRICHOPTERA

(caddisflies)**

78
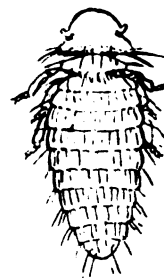
ORDER COLLEMBOLA
(springtails)

General Characteristics

The Collembola are small, often microscopic, primitively wingless insects with well developed legs and antennae. The mouth parts are of the chewing type, over grown by the cheeks (genae) which form a hollow cone. In some, however, the mandibles and maxillae are long and sharp resembling stylets. There are only six abdominal segments, the first of which bears a ventral tube or sucker, the third, a catch (tenaculum) that clasps a springing or jumping organ (furcula) attached to the fourth segment (Fig. 46).

Geographical Distribution

The Collembola are cosmopolitan in distribution.

Life Cycle and Habits

The Collembola develop without metamorphosis, the young resembling the adults except for size and sexual maturity. They are found on leaf mold, damp soil, decaying wood and leaves, the edges of ponds and streams, on the surface of standing water, along the sea shore, and even on the surface of snow. The egg laying habits are not well known, some lay eggs singly or in groups in the soil.

Relation to Man

Entomobrya multifasciata Tullb. and E. tenuicauda Schött have been reported as attacking man in Australia. The bites were similar to those of mosquitoes, producing sharp pain, irritation, and papules with intense itching.
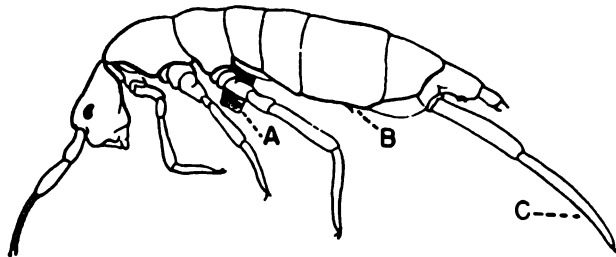
Figure 46.
Spring tail (A) ventral tube (B) catch (C) spring (after Willem)

PLATE XIII.

PRINCIPAL CHARACTERS FOR IDENTIFYING THE MOST IMPORTANT ORDERS OF INSECTS OF MEDICAL IMPORTANCE
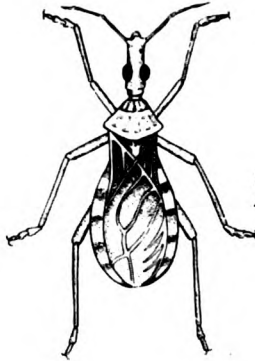
PROBOSCIS JOINTED, FLEXED
AND VENTRALLY PLACED

WINGLESS, BODY FLATTENED
DORSO-VENTRALLY.....LEGS
STOUT WITH CLASPING CLAWS.

HEMIPTERA
(true bugs)

ANOPLURA
(sucking lice)

WINGLESS, BODY LATERALLY
COMPRESSED.....LEGS ADAPTED
FOR JUMPING.
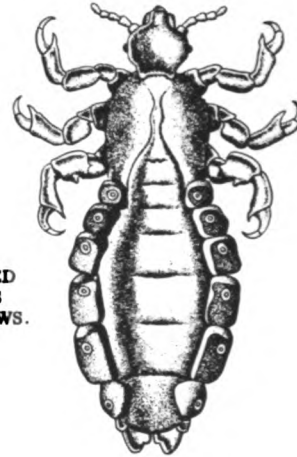
ONE PAIR WINGS
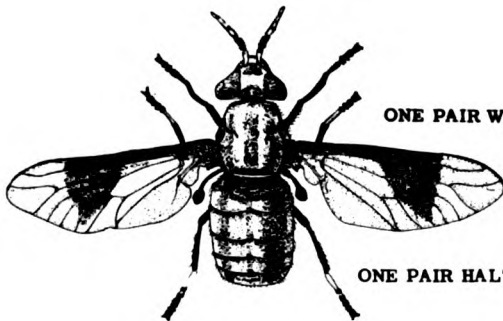
ONE PAIR HALTERES

DIPTERA
(flies, gnats, mosquitos)

SIPHONAPTERA
(fleas)

80
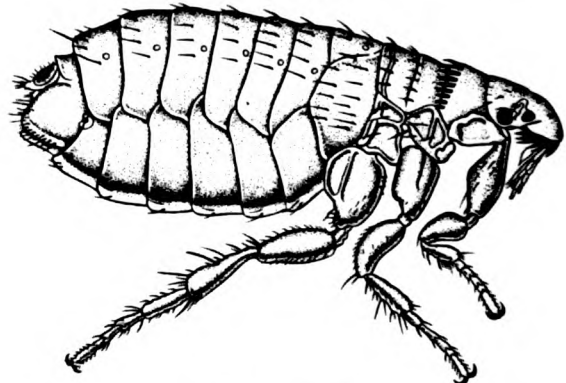
ORDER ORTHOPTERA
(cockroaches, grasshoppers, crickets and others)

General Characteristics

The Orthoptera are characterized as follows: The winged forms have the fore wings leathery, flexible and parchment-like with distinct venation. These cover the membranous hind wings which are folded fanlike when at rest. The mouth parts are formed for chewing. There are some forms without wings.

Family Blattidae (cockroaches) (Plate XII)

Geographical distribution: Cockroaches are widely distributed, but the greatest numbers are found in the tropics, fewer species in the temperate regions.

General Characteristics: The Blattidae are usually dorso-ventrally flattened insects with the head bent downward and backward under the body so that the mouth parts project caudally between the bases of the first pair of legs. There are normally two pairs of wings, the legs are modified for running instead of jumping, and the antennae are long.

Life Cycle and Habits: Cockroaches are much slower in development than other common insect pests. Their eggs are laid in more or less rigid capsules, or oöthecae, which are bean-shaped. The oötheca is separated down the middle and each side partitioned into separate chambers each enclosing an egg. The eggs are often carried around by the female, protruding from her abdomen for days before being dropped. In the case of the German roach they may hatch in about 28 days, the entire life cycle being completed in around 90 days. Metamorphosis is gradual, the nymphs resembling the adults except for size and, in the winged species, the development of the wing pads. Development is influenced by temperature, humidity, and available food, hence the life cycle is extremely variable.

Roaches are nocturnal in their habits, hiding during the day in sheltered, darkened crevices, foraging at night and disappearing rapidly when disturbed. Knowledge of their places of concealment is usually the key to their control.

There are over 3,500 species, only a few of which are closely associated with man. Those frequenting homes become established in heated buildings in temperate climates, migrating out of doors somewhat during the summer. In the tropics and semi-tropics they may be found in unheated abodes and outdoors at all times. They live preferably in damp situations.

Thorough cleanliness and the protection of food supplies are extremely important in roach control. In mild climates, reinfestation is common in loosely constructed buildings, and periodic control is necessary.

81

Relation to Man: Because of their filthy habits, cockroaches are potential vectors of disease. They visit sewers, privies, septic tanks, cesspools, dead animals, bloody bandages, pus and all manner of contaminated materials. In turn, they visit delicate human food, dishes, cooking utensils, and the surfaces utilized in the preparation of food. In addition they have been known to enter the mouth, ear-canals and nostrils during sleep causing irritation and discomfort. In sleeping rooms in the tropics they have been known to bite man. Children have had wounds covering the body as a result of their bites. They feed on sores and even dead human bodies. It is very probable that cockroaches rival flies as mechanical carriers of infectious agents. There is every opportunity for them to contaminate food by their dead bodies, feces, regurgitations, and pathogenic organisms. Rotn and Willis (1957) have shown that they are naturally infected with many species of pathogenic bacteria, one species of pathogenic protozoa and 12 species of helminths. They have listed them as naturally carrying the following pathogens: Several Staphylococci including the species Staphylococcus albus and S. aureus (abscesses, boils, etc.), Escherichia coli (Migula) (urinary infection), Parcolobactrum aerogenoides Borinan, Stuart & Wheeler (gastroenteritis) Proteus morganii (Winslow et al) (infant summer diarrhea), P. vulgaris Hauser (urinary-tract infections, abscesses), many species of Salmonella (gastroenteritis, food poisoning, typhoid fever), Shigella paradysenteriae (Collins) (dysentery), Pasteurella pestis (Lehmann & Newman) (plague), Bacillus subtilis Cohn, Clostridium perfringens (Veillon & Zuber) (gaseous gangrene), Mycobacterium leprae (Armauer-Hansen)(leprosy), Entamoeba histolytica Schaudinn (amoebic dysentery), Enterobius vermicularis (Linn.) (human pin worm), Ascaris lumbricoides Linn. (ascariasis), Ancylostoma duodenale (Dubini) (hookworm), Necator americanus Stiles (tropical hookworm), Trichuris trichiura (Linn.) (whipworm) and many others.

They also record them as the experimental vectors of such diseases as: poliomyelitis, Coxsackie viral diseases, yellow fever, Asiatic cholera, cerebrospinal fever, gastroenteritis, diphtheria, pneumonia, typhoid fever, undulant fever, glanders, anthrax, tetanous, tuberculosis, giardiasis, balantidiasis, schistosomiasis, and taeniasis.

ORDER EPHEMEROPTERA
(mayflies, shadflies, lakeflies)

General Characteristics

Mayfly adults are slender, soft-bodied insects with membranous, triangular wings containing many veins and cross veins (net-like venation). The second pair of wings are much smaller or wanting.. The mouth parts are vestigial although those of the immature stages are of the chewing type. The abdomen is fitted with two or three long, filamentous appendages (Plate XII). The young are aquatic and resemble the adults in general structure.

Geographical Distribution

World wide.

Life Cycle and Habits

Each adult female may lay several thousand eggs in her lifetime, swooping down and releasing them into the water. They hatch in less than a month into aquatic nymphs which live from a few weeks to three years depending upon the species. The metamorphosis is gradual but unusual in that an aquatic nymph leaves the water and molts into a winged nymphal stage, which gives rise to the adult through another molt one or two days later. The adults do not feed, and live only a day or two. They often emerge in swarms in July and August appearing as clouds along streams, lakes and in nearby cities.

Relation to Man

The swarms of these insects contain so many individuals that their dead bodies often cause disagreeable odors. The cast skins from the process of molting from the winged nymph to the adult stage will be found on trees, grass, shrubs and structures. As they disintegrate, people breathing the fine particles of cast skins borne by the wind may become sensitized, resulting in severe asthmatic paroxysms. A common species Hexagenia bilineata (Say), has been found responsible for this condition in Ohio.

ORDER TRICHOPTERA
(caddisflies)

General Characteristics

The Trichoptera are nocturnal, moth-like insects with membranous wings, the front pair longer and narrower than the metathoracic pair. The longitudinal veins of the wings are normal, but the number of cross veins is reduced. The body is soft, and covered with long hairs. The wings likewise are generally covered with long hairs and occasionally a few scales are present; sometimes, however, the wings are almost naked. They are held rooflike over the body when at rest (Fig. 47). The antennae and legs are long, the tarsi five segmented. The mouth parts are vestigial with the exception of well developed palpi.

Geographical Distribution

Cosmopolitan, but usually uncommon in the tropics except in the highlands.

Life Cycle and Habits

The adult females lay several hundred to a thousand eggs, entering the water and placing them on stones, shells and other materials, or fastening them above the surface on overhanging branches. These latter are said to hatch when moistened by rains. The larvae are aquatic, inhabiting cold, unpoluted, fresh water lakes and streams. This group has developed the art of case-making, using sand grains, small stones, leaves, sticks and many other materials in the construction of the larval case. The full grown larva spins a cocoon in which it pupates beneath the surface of the water. The pupae are unique in having strong mandibles which aid in escaping from the cocoon. After releasing itself, the pupa swims to the surface, crawls out upon a stone or other protruding object and the adult emerges. The life cycle is completed in about a year, the majority of it spent in the larval stage. Adult life is about one month.

Relation to Man

The caddis flies are responsible for allergies such as hay fever and asthma brought about by the inhalation of hairs and scales from their wings and bodies. They, like the Ephemeroptera, appear in great numbers around streams and lakes, affording an opportunity for the hairs and scales to become airborne.

*Redrawn from Oman

Figure 47*
Caddisfly

84

ORDER MALLOPHAGA
(biting, or chewing lice)

General Characteristics

The Mallophaga are chiefly parasites of birds although some species are found on mammals. They are <u>flattened wingless forms</u>, of small size (1 to 5 mm.), with the <u>head broader than the thorax</u> (Fig. 48). The <u>mandibles are distinct</u>. Their development is without metamorphosis.

Geographical Distribution

Cosmopolitan.

Life Cycle and Habits

The life cycle is spent entirely on the host with continuous generations. The eggs are glued to the feathers or hair. The young resemble the adults in appearance, being slightly lighter in color. The tarsi of the bird-feeding species have two claws, and are adapted to running, while those feeding on mammals have one claw that folds against the tibia for holding to hairs. Their food consists of hair, clotted blood, parts of feathers, and debris.

Relation to Man

The mallophaga often annoy poultry handlers, but since they do not remain long on the host, the annoyance is only temporary. The dog tapeworm, <u>Dipylidium caninum</u> (Linn.), utilizes the biting dog louse <u>Trichodectes canis</u> DeGeer, or a flea <u>Ctenocephalides canis</u> (Cortis), as an intermediate host. This tapeworm is occasionally found in man. Chicken lice are responsible for loss of weight, reduction of egg laying capacity, and even death of chickens, turkeys and other fowl.
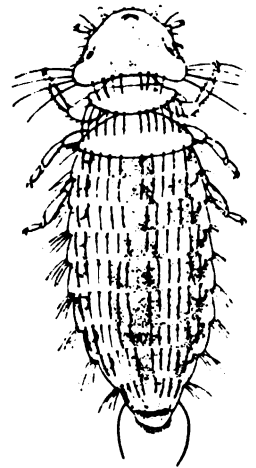
Figure 48 *
Mallophaga

*Redrawn from Bishopp & Wood

ORDER ANOPLURA
(sucking lice)

General Characteristics

The sucking lice are <u>small wingless ectoparasites</u> with dorsal spiracles and <u>soft flattened bodies</u>. The <u>tibiae and tarsi are fitted for grasping hairs by a single tarsal claw</u> which is <u>opposed by a toothed projection of the tibia</u> (Plate XIII). Their development is without metamorphosis. They may be distinguished from the Mallophaga by their <u>piercing-sucking mouth parts</u>. The skin-piercing <u>stylets</u> are normally <u>retracted into the head</u> and are projected only during the blood-sucking process. The order includes about 400 species, but only two suck the blood of man.

Family Pediculidae

General Characteristics: This family includes the two species feeding upon man. These lice are characterized by having <u>conspicuous eyes, depressed bodies</u>, and <u>indistinctly segmented thoraces</u> (Fig. 49).
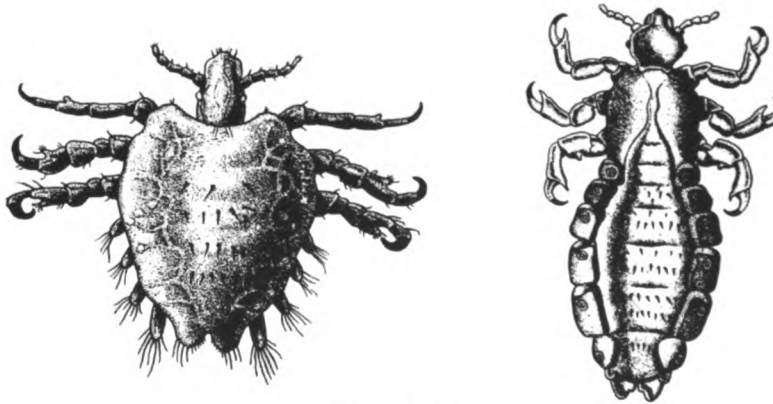
Figure 49
A. <u>Phthirus pubis</u>, the crab louse. B. <u>Pediculus humanus</u>, the body louse.

Geographical Distribution: Cosmopolitan, but is less abundant in the tropics.

Life Cycle and Habits: The lice infesting man require a period of roughly 3 to 4 weeks for their development. The entire life cycle is spent on the host. Generations are continuous throughout the year. Since there is no metamorphosis, the young resemble the adults except for size. The pubic lice, and the "head strain" of <u>Pediculus humanus</u> Linn. attach their eggs (nits) to hairs, while the "body strain" of <u>P</u>. <u>humanus</u> glues its eggs to fibers in the seams of clothing (Fig. 50). These eggs hatch in about a week. In unused clothing, however, body lice eggs may remain viable but unhatched for as long as 5 weeks.

86
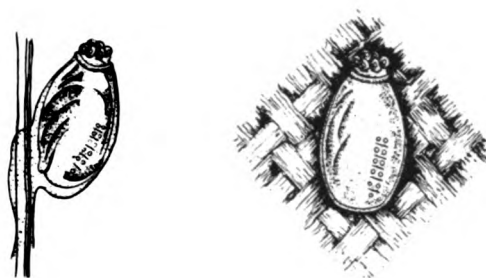
Figure 50
Eggs of lice

The front of the head of a louse is produced into a very blunt snout bearing a ring of recurved hooks. This ring is called the haustellum. When the louse feeds, it presses its haustellum against the skin, rolls out the hooks until they are firmly attached, and then forces the stylets deep into the skin. Since these stylets are normally retracted within the head, they are not seen in ordinary whole mounts.

Relation to Man: The bite of the head and body louse, Pediculus humanus, provokes rosy swellings and, coupled with the ensuing scratching, produces the characteristic scarring and bronzing of the skin referred to as "vagabond's disease." The term pediculosis is usually used for an infestation with lice. The reaction is thought to be caused by a sensitization due to saliva and feces deposited by the insects on the abraided human skin. The same species transmits epidemic typhus, a disease caused by Rickettsia prowazeki da Rocha-Lima, which produces a case fatality varying from as low as 5 per cent to as high as 70 per cent in epidemics among undernourished refugee populations. Transmission is usually accomplished by scratching the infected crushed lice or their feces into the site of the bite or into the excoriated skin, or by the insects' mouth parts. The rickettsiae enter the epithelial cells lining the stomach, multiply there and are later discharged into the body cavity or the stomach where they are either eliminated with the feces, liberated when the louse is crushed, or find their way into the salivary glands to be inserted with the saliva when the louse feeds. The rickettsiae remain active during the life of the louse, which is shortened to about 12 days by the infection. Clothing containing louse feces may transmit the disease through contact with mucous membranes, or the rickettsial laden dried feces may pollute the air where they may be inhaled.

It has been shown that murine typhus caused by Rickettsia typhi Wolbach and Todd, can be transmitted from man to man by the body louse.

Pediculus humanus also transmits louse-borne relapsing fever caused by a spirochaete, Borrelia recurrentis Lebert. For successful transmission, the infected lice must be crushed and rubbed into the abraided skin or into the conjunctiva of the eye. Neither the feces nor the bite is infectious. The disease is normally epidemic

PLATE XIV

PICTORIAL KEY TO LICE OF DOMESTIC RATS
IN SOUTHERN UNITED STATES

Abdomen with well de-
fined ventral, lateral
and dorsal plates

Abdomen with plates
poorly defined or
absent

ADULTS

NYMPHS

Lateral plates small,
subtriangular. Segment
II of antenna as long
as wide

Lateral plates large,
emarginate posteri-
orly. Segment II of
antenna longer than
wide

Abdomen with spira-
cles and two parallel
rows of setae

Abdomen without
spiracles or paral-
lel rows of setae

SPIRACLE

Polyplex spinulosa

Polyplex spinulosa

Hoplopleura spp.

Lateral plates 4-6
with one large and
one minute seta

Lateral plates 4-
6 with two large
setae

Hoplopleura oenomydis

Lateral plates broad-
ly emarginate; Apical
processes thorn-like

Lateral plates narrow-
ly emarginate; Apical
processes broad

Prepared by Roy F. Fritz and H. D. Pratt

88

Hoplopleura hirsuta

Hoplopleura acanthopus

CMEX-ATLANTA, GA.

whereas tick-borne relapsing fever is endemic. The louse ingests the spirochetes with the patient's blood and the parasites find their way into the hemocele where they multiply. Since they do not re-enter the digestive tract, they cannot be found in the feces.

A third louse-borne disease, trench fever is of minor importance, at least under present combat conditions. The causative agent is believed to be a rickettsia, Rickettsia quintana da Rocha-Lima. The organisms multiply in the louse on the wall of the mid-gut, but the method of human introduction is not known.

Tularemia, caused by Pasteurella tularensis (McCoy and Chapin), is said to be transmitted to a variety of animal hosts by ticks, flies, fleas and lice.

The etiologic agent of rickettsialpox has been established experimentally in body lice, and plague bacilli have been found in lice on rodents in Montana. Experimentally lice have been implicated in the transmission of typhoid organisms through the medium of their feces.

ORDER HEMIPTERA
(true bugs)

General Characteristics

The Hemiptera have a jointed fleshy proboscis attached anteriorly which when not in use is flexed under the head. The mouth parts are of the piercing sucking type (Plate XIII.). The winged members of this order have each of the front wings modified into a thickened basal portion, and a membranous distal portion. The membranous portions often overlap. The thickened basal half resembles the wing covers (elytra) of beetles. The second pair of wings are membranous and folded beneath the front wings.

The habits of the families of this order vary greatly, certain families are aquatic but air breathers, others live on the surface of the water, and some are entirely terrestrial. The metamorphosis is gradual.
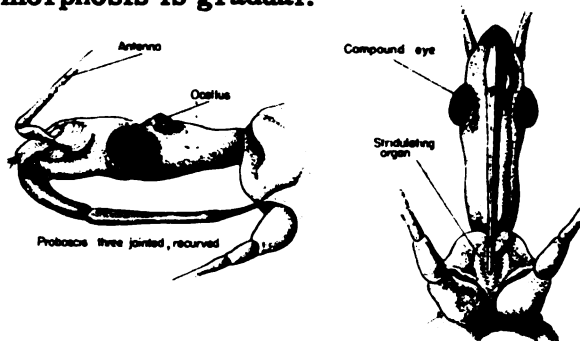
Figure 51
Head and proboscis of a blood-sucking hemipteron. Note stridulating organ on the prosternum, characteristic of the Reduviidae.

89

Family Reduviidae (conenose bugs, assassin bugs, kissing bugs)

General Characteristics: The family Reduviidae has a short, three-segmented beak which is attached to the tip of the head. The prosternum is grooved for the reception of the beak when at rest. The antennae are four segmented and the anterior portion of the head is elongated and cone-shaped (Fig. 51).

Geographical Distribution: Panstrongylus megistus (Burm), South America, widely disseminated in Brazil and British Guiana; Panstrongylus geniculatus (Latr.), Panama and Northern South America; Triatoma sanguisuga (Lec.) South and Southwestern United States; Triatoma infestans (Klug), Uraguay, Argentina, Brazil, Bolivia, Chili, and Paraguay; Rhodnius prolixus Stal, Mexico, Panama, El Salvador, and South America.

Life Cycle and Habits: There are over three thousand species of reduviids, about one hundred of which have developed the blood sucking habit. The latter are generally abundant in the warm areas of the New World from the Southern United States to South America. The greater majority are predaceous, sucking the blood of other insects, giving rise to the name "assassin bugs." Those that have acquired the habit of sucking the blood of warm blooded animals have a slender straight beak, and the antennae are inserted on the sides of the head between the eyes and the end of the beak, while the predaceous forms have a coarse, curved beak and the antennae are situated on top of the head.

The reduviids normally inhabit the burrows or nests of animals, but a few feed on man and his domestic animals. The eggs are glued into cracks and crevices in houses or in the nests of the hosts. They are laid singly or in small batches, each female ultimately laying 100 to 300 eggs. After an incubation period of eight days to a month, the first instar nymphs emerge. A blood meal is necessary before each molt, the time spent in each instar being about 40 to 50 days. The entire life cycle usually requires from one to two years.

Relation to Man: Members of several reduviid genera including Triatoma, Rhodnius, and Panstrongylus are important vectors of the causative organism (Trypanosoma cruzi Chagas) of Chagas' disease, or American trypanosomiasis. The most important species are Triatoma infestans, Rhodnius prolixus and Panstrongylus megistus, but Triatoma dimidiata (Latr.) and several others are important in some areas from Mexico to South America.

The adults of both sexes bite and may attack man. The bite of a blood sucking reduviid is usually so painless that one who is bitten during sleep is not awakened. They often feed on the cheeks or at the angle of the mouth. During the blood meal, which may last from a few minutes to half an hour, the insect deposits a small amount of liquid feces on the skin near the puncture made by the proboscis. Reduviids that take blood from persons infected with the causative agents of Chagas' disease usually harbor these

90

organisms in their bodies for life. Infection of man takes place by the scratching or rubbing of infective feces into the excoriated skin at the site of the bite. Only species that defecate while taking a blood meal are good vectors. Transovarial transmission does not occur, but certain Triatoma have been known to suck the blood of other reduviids in the nest, and Rhodnius is reported to feed on their excreta, so it is entirely possible that in this manner, and through general contamination with feces, the trypanosomes may be transferred from insect to insect. The organisms normally occur in dogs, cats, bats, squirrels, monkeys, opossums and armadillos in infected areas.

Ten species of reduviids have been found naturally infected in the United States, in Texas, Arizona, New Mexico and California. Wild rodents and opossums have also been found to be infected in these states, but there have been no infections in man.

Chagas' disease causes stunted human development and a wasting away of the body, with marked anemia, enlarged thyroid glands, and an elevated temperature. The disease often becomes chronic within a month if death does not occur.

There are several reduviid bugs that have not developed the blood sucking habit, but which may bite man producing great pain. Triatoma sanguisuga in the Southern and Southwestern United States has a very painful bite which results in red spots and welts. It has been reported as infected with the Western strain of equine encephalomyelitis. The "kissing bug" Reduvius personatus (Linn.) causes severe temporary pain by a strong salivary toxin. The wheel bug, Arilus cristatus (Linn.) also has a bad reputation.

Classification of Important Genera: The important genera are separated by the position of the antennal insertion. In Rhodnius, the insertion is at the tip of the head; in Triatoma, the insertion is midway between the compound eyes and the tip of the head; while in Panstrongylus, the insertion is near the compound eyes (Fig. 52).

Triatoma rubrofasciata De Geer   Panstrongylus geniculatus Lat.   Rhodnius prolixus Stal.
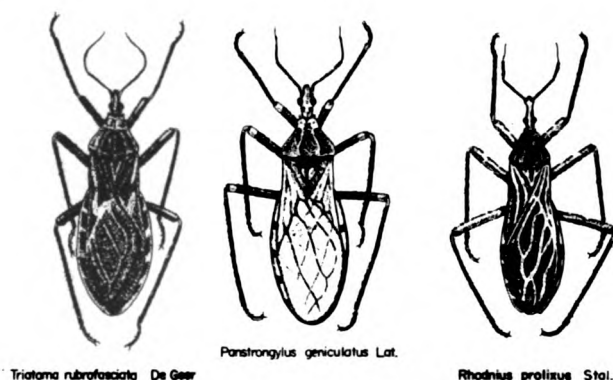
Figure 52
Three medically important reduviids

Family Cimicidae (bedbugs)

General Characteristics: The members of this family are dorsoventrally flat-tened, wingless insects, of a reddish-brown color. The body is broad, the prothorax large, bearing flattened lateral projections and indented in the form of a half circle to receive the head. The wings are represented by mesothoracic pads which cover most of the metathorax. The tarsi are three segmented. The head bears prominent eyes laterally. The antennae are four segmented, the beak three. The tip of the abdomen of the male is more or less pointed, while it is rounded in the female. The entire body is pitted, with the pits bearing bristles (Fig. 53). The adults have stink gland openings on the last segment of the thorax between the hind legs. The nymphs also have stink glands, but located elsewhere. These glands give the group their charac-teristic disagreeable odor.

Geographical Distribution: Cimex lectularius Linn. is cosmopolitan in distribu-tion throughout the temperate regions. C. hemipterous (Fabr.) is tropical and sub-tropical. C. boueti Joyeux, is tropical and is found in Africa and South America. There are less than forty known species.

Life Cycle and Habits: The eggs, which are large and yellowish-white, are laid at the rate of approximately two to eight per day, glued by secretion to cracks and crevices and under wall paper. The females often return to the same places to continue oviposition, thus causing an accumulation of eggs in one group. Each female may average 100 to 250 eggs during her lifetime.

In warm weather the eggs usually hatch in from six to ten days, in cooler weather the time may be extended to as much as 30 days. The young nymphs resemble the adults except for size; and molt five times before becoming adults. They must have a blood meal between each molt. There are no wing pads evident until the pre-adult nymphal stage. The life cycle requires from seven to ten weeks. They forage for food at night, hiding in crevices during the day.
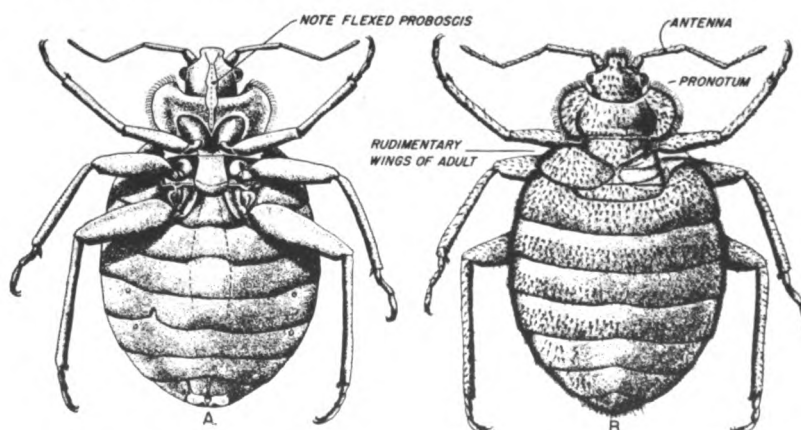
Figure 53
Adult Cimex lectularius, the bedbug

Relation to Man: Some individuals are not adversely affected by the bites of bedbugs, while in others the irritating salivary secretions cause whitened, hard swellings or wheals. Excessive bites over a period of time may result in nervousness, anemia, insomnia and general debility.

Although these insects have not been incriminated in the natural transmission of any disease, experimentally a number of disease organisms can be transmitted by inoculations of macerated bugs or by their feces. Leptospirosis has been shown to be experimentally transmitted by their bites. Leishmania donovani (Laveran et Mesnil) and L. tropica (Wright) can be incubated in the bedbug, but they have not been found to transmit the diseases. This is also true for the rickettsias of murine and epidemic typhus. Experimentally they can transmit European relapsing fever to mice.

Few bacteria become established in the alimentary tracts of bedbugs because of antibacterial substances found there which inhibit bacterial growtn. However, Pasteurella tularensis is retained in a viable state in the insect for life, tue feces are infective, and it has been transmitted from mouse to mouse for days. Similarly, plague bacilli develops slowly in bedbugs with their feces remaining infective up to 48 days. Undulant fever has been experimentally transmitted by them as well as by fleas and ticks. With all this experimental evidence, bedbugs may mechanically transmit pathogenic organisms, but they have not been shown to be the natural vectors of any disease.

ORDER COLEOPTERA
(beetles)

General Characteristics

There are both winged and wingless members of the Order Coleoptera. Those with wings have two pairs, the first pair thick and horny without veins, and serving as covers (elytra) for the hind wings. These elytra, when at rest, meet in a straight line down the back (Plate XII). The second pair are membranous, and fold back under the elytra. The mouth parts are of the chewing type. Metamorphosis is complete.

Family Meloidae (blister beetles)

General Characteristics: The blister beetles are soft bodied insects with broad heads. The head sharply narrows into a neck where it meets the prothorax. The wing covers are wider than the prothorax. The legs are long with the fore and middle tarsi five-jointed and the hind tarsi four-jointed. There are about 2,000 known species of this family.

Geographical Distribution: Cosmopolitan. Lytta (Cantharis) vesicatoria (Linn.) (Spanish fly) is found in Soutnern Europe and in Russia.

Life Cycle and Habits: The female deposits from 50 to over 250 eggs in the ground. The campodeiform larvae developing from the eggs are called triungulins. This first instar must seek out a grasshopper egg pod or a nest of bees for food. By molting, the triungulin gives rise to the second stage larva which is either soft, short-limbed, and eruciform, or less often, a modification of the first instar type called the caraboid stage. The next molt brings forth the scarabaeoid larva which resembles the larva of a scarab. All of the above stages are summer forms. The scarabaeoid larva finally changes into a pseudopupa or coarctate larva which over-winters. In the spring another molt gives rise to an active stage which then pupates. The coarctate larva may remain in the soil for a year or more. There is normally one generation a year. This type of development is termed hypermetamorphosis.

Relation to Man: A volatile substance, cantharidin, is found in the Meloidae, most concentrated in the genitalia. When these soft bodied beetles are accidentally crushed on the skin, a vesicular dermatitis is produced. The physician can usually discriminate between this condition and that caused by insect bites by the absence of a puncture wound.

Family Staphylinidae (Rove beetles)

General Characteristics: The rove beetles are normally very small insects with long slender bodies and very short elytra. The abdomen is often raised and curved forward over the body as if it could sting.

Geographical Distribution: World wide distribution.

Life Cycle and Habits: These beetles are common around decaying plant and animal life, being found around manure piles, and under stones, beneath bark and fungi. The larvae develop in the same situations as the adults and resemble them in body form.

Relation to Man: Certain Staphylinidae contain an irritating substance in all parts of the body. When the insect is crushed on the skin this irritant causes cell damage, with chronic sloughing of dead skin, which does not heal rapidly. The blistering effect does not occur for one or two days after the beetle is crushed on the skin.

Apparently only the genus Paederus possesses a vesicant. Various species of this genus are found in Tropical, South, and Eastern Africa, Java, Brazil and Equador.

Other Families

The family Paussidae of Southeast Africa is reported to have a blistering effect on the skin when crushed. The larvae of a leaf beetle of the family Chrysomelidae, Diamphidia simplex (Say), has such a potent hemolytic toxalbumen that South African Bushmen use the poison on the tips of their arrows.

94

Canthariasis

This is a term given to the infection of the body by beetles or by their eggs or larvae. They have been recorded as cutaneous, intestinal, urinary, nasal and ocular in form. It is relatively rare in occurrence, and is caused by the accidental entrance of these forms into the body. There have been several instances where larvae or adults of beetles have been found infesting the digestive system of man as well as rarely in the rectum or sinuses.

Coleoptera as Hosts of Helminth Parasites

Gongylonema pulchrum Molin is one of the nematode worms, the eggs of which are ingested by species of dung beetles in feces of the reservoir hosts, monkeys, bears, pigs, ruminants or hedgehogs. The eggs hatch in the intestines of the beetles, the larvae ultimately reaching the body cavity. Man becomes infected by accidentally swallowing the beetles, or from drinking water containing larvae released from decaying insects.

Moniliformis moniliformis (Bremser): As in the above case the eggs enter the intestines of insects, reach the body cavity and encyst. In this case the insects are beetles and cockroaches. The reservoir is found in rats. Human infections have been reported from Italy, Africa, and British Honduras.

Macracanthorhynchus hirudinaceus (Pallas): Scarabaeids are the intermediate hosts of this thorn-headed worm, which has been found in man in Russia and is a natural parasite of swine.

Hymenolepis diminuta (Rudolphi): The rat tapeworm has as its intermediate hosts several genera of beetles as well as other arthropods. The life cycle in the insect is the same as for those above, the beetles obtaining the eggs from rat or mouse droppings. Man becomes infected after swallowing the intermediate hosts; either the animal ectoparasites, or beetles infesting pre-cooked cereals or dried fruits.

Raillietina cesticillus (Molin): The fowl tapeworm. Many species of beetles serve as the intermediate hosts of this tapeworm. It has not been reported as a parasite of man.

ORDER LEPIDOPTERA
(moths and butterflies)

General Characteristics

The Order Lepidoptera (Plate XII) is characterized by the possession of four large wings which are membranous and covered on both sides with scales that overlap. The body and other appendages are also covered with scales. The mouth parts are of the sucking type, coiled under the head when not in use.

Urticating Lepidopterous Larvae

Certain larvae (caterpillars), in about eight families of this order, bear setae or spines that have urticating properties. The structures that are associated with this phenomenon are of two types. The primitive hair type is a small, stiff, hollow seta connected with a single glandular hypodermal cell which fills it with venom. These setae may be open at the top and thus release the material, or they may fracture easily upon contact with the skin, and cause great irritation. They retain their urticating properties for a considerable length of time after they are broken off. The other type is a large, hollow, frequently chitenized spine with the interior filled or lined with several venom producing hypodermal cells. When a spine of this type touches human skin it penetrates, the tip breaks off or a terminal plug opens, and the venomous secretions are released. These secretions may cause mild to serious eruptions of the skin accompanied by itching, and often systemic disorders.

Examples of urticating caterpillars are found in the larvae of the flannel moth (Fig. 54), the browntail moth, tussock moth, and in the puss, and saddle back caterpillars.

When such spines or hairs are contacted they may produce urtication (wheals) or vesication (blisters) depending upon the species. The symptoms may range from a simple redness of the skin to an inflammation with circumscribed elevations, and blisters. There is an intense burning pain, and there may be severe swelling of the affected portion. There may also be manifestations of anxiety, nervousness, nausea, muscle cramps, headache, and labored breathing. The symptoms may last for almost a week. If the contact was in the neck region, paralysis may result.

Megalopyge opercularis S. & A. is an important species of urticating larva in the United States. In Texas during one season there were thousands of cases of urticaria. The abundance of the caterpillars on school playgrounds caused the closing of the schools. Nettling hairs are sometimes borne by the wind and produce painful inflammation of the conjunctiva, marked by the formation of round, gray swellings where each hair is embedded (ophthalmia nodosa). Likewise, windborne hairs falling in drinking water have caused inflammation of the mucous membranes of the mouth.

96

The range caterpillar, <u>Hemileuca oliviae</u> Cockerell, is reported to cause asthmatic attacks with acute catarrhal conditions and coughing in New Mexico.

<u>Lepidoptera as Hosts of Helminth Parasites</u>

<u>Hymenolepis diminuta</u> (Rudolphi), the rat tapeworm, has the meal moth <u>Pyralis</u> <u>farinalis</u> as one of its intermediate hosts.
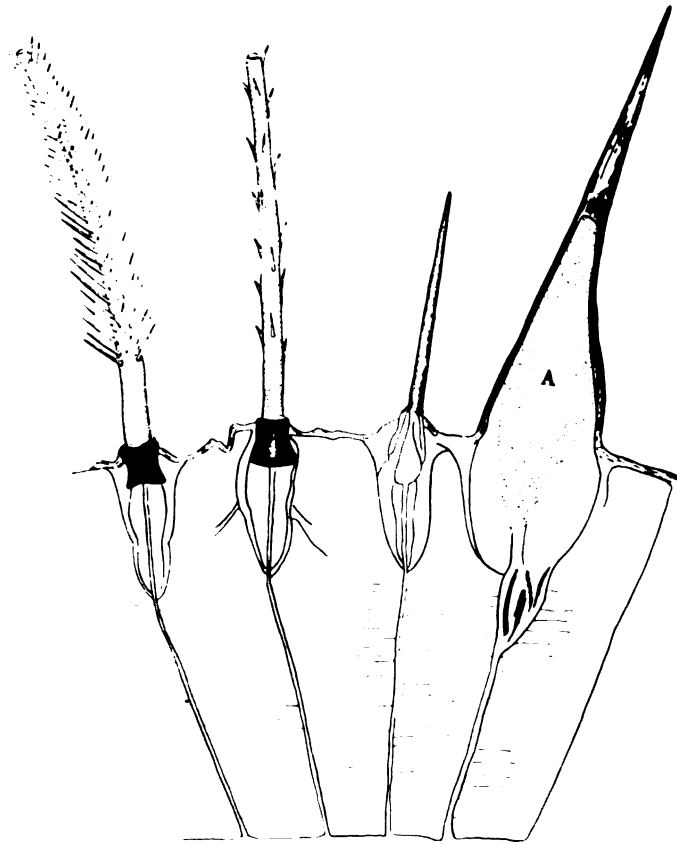
<u>Figure 54</u>
White Flannel Moth, <u>Lagoa crispata</u>. Section through body
wall showing hairs and spines. (A) Venom sack. (Redrawn
from Baerg, 1924).

General Characteristics

Fleas form a well-defined group, easily distinguished from all other insects,
both by their structure and their habits. All are ectoparasites of birds and mammals.
They are small, brown, hard-bodied insects, completely devoid of wings, a deficien-
cy partly compensated for by their powerfully developed legs especially adapted for
jumping. Unlike most parasites, they are very active and nimble and are capable of
jumping upward to a height of 7 inches and horizontally nearly twice that distance. The
laterally compressed bodies and numerous stout, posteriorly directed spines enable
them to move readily through the hairs or feathers of their hosts (Plate XIII). The an-
tennae are short, three-segmented, and knoblike, partly concealed and protected in
grooves at the sides of the head. True compound eyes are lacking, but some species
possess degenerate eyes without distinct facets, while others are completely blind.
In some species, a conspicuous row of very stout spines, or "comb," is located just
above the mouth parts, and also on the pronotum. The mouth parts are especially
adapted for piercing the skin and sucking blood, which is the only food known to be
taken by adult fleas of both sexes (Fig. 55). Metamorphosis is complete (Fig. 56).
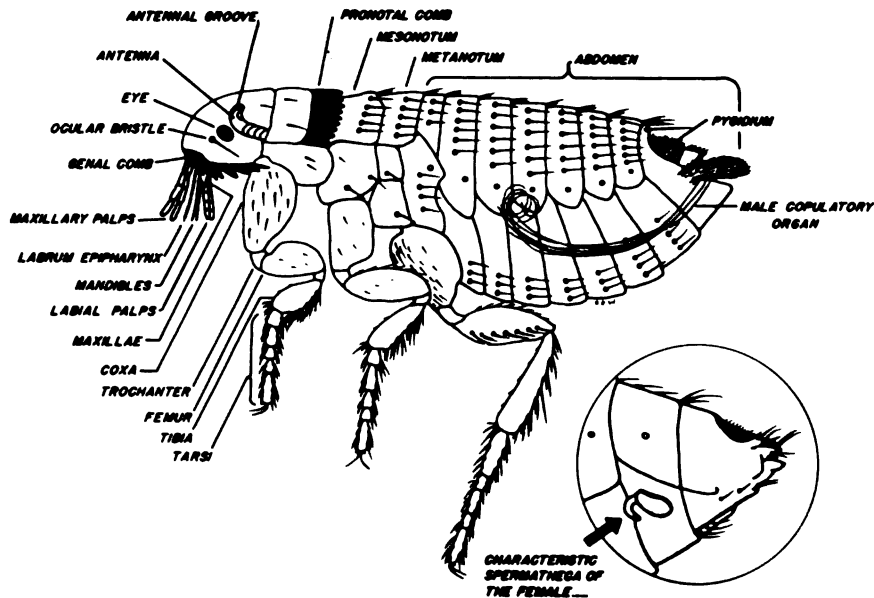
Figure 55
Anatomy of a flea

98

Geographical Distribution

The following species are of medical importance in the areas listed: Xenopsylla cheopis Roth: Tropical and subtropical, generally widely disseminated; X. brasiliensis Baker: Tropical Africa, India, carried to Brazil and England by shipping; X. astia Rothschild: India, Ceylon, Mesopotamia, Mombasa; X. nubicus (Rothschild): Africa; X. eridos (Rothschild): South Africa; Pulex irritans Linn.: Cosmopolitan; Stivalius ahalae: South India; S. cognatus: Java; Neopsylla setosa (Wagner): U.S.S.R., Mongolia, Manchuria; Diamanus montanus (Baker): Western and Southern United States; Oropsylla silantiewi (Wagner): Russia, India; Nosopsyllus fasciatus (Bosc.), almost cosmoplitan but generally limited to temperate zones; Echidnophaga gallinacea (Westw): Japan, Australia, Central Asia, North Africa, United States; Tunga penetrans (Linn.): America, Tropical Africa, Madagascar; Ctenocephalides canis (Curtis): Cosmopolitan; C. felis (Bouche): Cosmopolitan.

Life Cycle and Habits

Most fleas remain on their hosts less constantly than do lice, but they visit their hosts more frequently than do bedbugs. The nest or burrow of the host is the home of the egg, larva, and pupa, and frequently of the young or the ovipositing adult, although the eggs may be carried on the hair of animals into houses where they drop off and hatch. The larvae develop and pupate in the nests or dens, and it is significant that those mammals which have no permanent habitation, such as the monkey and deer, are nearly free from fleas, although they seldom lack lice. The fact that fleas leave the body of a dead host as soon as it becomes cold is of particular importance in the spread of flea-borne diseases.
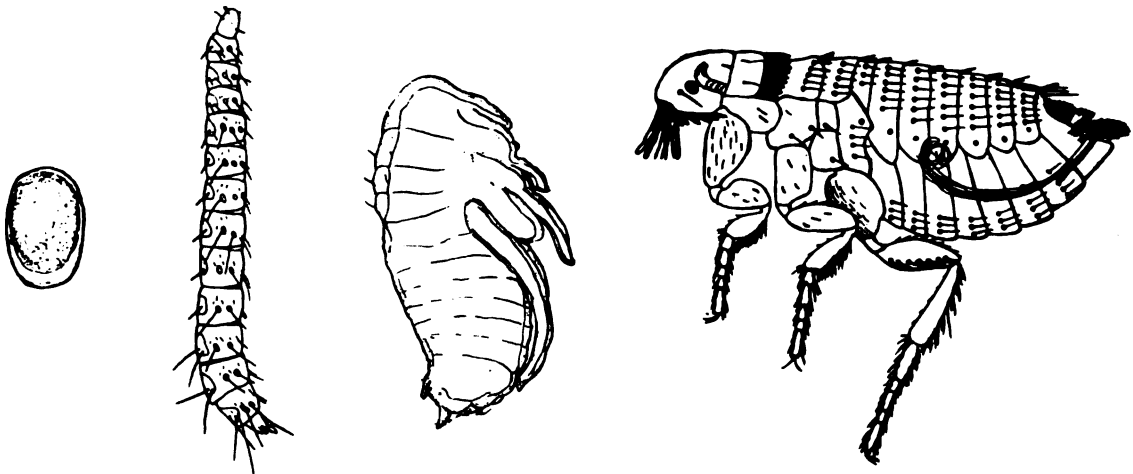
Figure 56
Life cycle of a flea. Egg, larva, pupa (removed from cocoon), and adult

99

Eggs: These are oval, pearly-white objects dropped at random in the fur of the host, in the dust and debris of floor cracks, under rugs, and in nests or burrows. The incubation period varies from 2 to 12 days.

Larvae: Flea larvae are tiny, cylindrical, maggot-like creatures with neither legs nor eyes (Fig. 56). They have brown heads and whitish bodies which are provided with rather sparse, bristly hairs that aid them in crawling (Fig. 56). The body is terminated by a pair of tiny hooks. Under favorable conditions of temperature and humidity, the larvae pass through two molts and enter the pupal stage in 10 to 12 days. The larvae feed on material found in the host's nest, such as dried animal feces, dead insects, nest building material, adult flea feces and dried blood mixture.

Pupae: When they are ready to change into pupae, the larvae may utilize particles of sand, earth, or refuse, gluing them together into cocoons, or they may loosely spin silken threads in small depressions for the support of groups of cocoons. The adults sometimes emerge from the pupae in about 5 to 14 days but may require longer at low temperatures.

Relation to Man

Unlike most blood-sucking insects, fleas feed at frequent intervals. They do not remain on one host, but feed temporarily, and transfer to several other hosts which may be of an entirely different species. The dog flea will feed on man as well as on dogs and cats. For this reason, and the fact that fleas insert their mouth parts to suck blood, they are particularly prone to transmit pathogenic organisms. The frequent biting is due to the fact that fleas are very easily disturbed while feeding and seldom complete a meal at one time.

Fleas of medical importance are of the following families and genera:

Pulicidae; Pulex - Echidnophaga - Ctenocephalides - Xenopsylla

Ceratophyllidae; Diamanus - Nosopsyllus - Oropsylla

Pygiopsyllidae; Stivalius

Neopsyllidae; Neopsylla

Tungidae; Tunga

Plague: Fleas frequently feed even when their digestive tracts are already filled, and they may pass practically unaltered blood in their feces. Virulent plague bacilli (Pasteurella pestis) rubbed into recent flea bites may result in infection of man or animals, but the usual method of plague transmission is by regurgitation. The rat flea, after feeding on an infected animal, often has its digestive tract completely blocked by

solid growths of plague organisms. Such "blocked" fleas are unable to ingest more blood, but in attempting to do so, regurgitate great quantities of plague germs into their victims. Fleas may remain infective for a long time, but many fleas die when "blocked," especially in hot or dry weather, since they are unable to overcome the effects of dessication by imbibing fresh blood.

Plague found in wild rodents is termed "sylvatic plague." Ground squirrels and a great variety of native rodents have been found naturally infected in the United States, and fleas are the vectors from animal to animal.

Some fleas concerned with the transmission of "murine plague" (rat borne) are: The Oriental or Asiatic rat flea, Xenopsylla cheopis, X. brasiliensis, X. astia, X. nubicus, X. eridos; the human flea Pulex irritans; Stivalius ahalae, S. cognatus; Neopsylla setosa; Diamanus montanus; Oropsylla silantiewi, and Nosopsyllus fasciatus.

Endemic Typhus (murine typhus): This disease is caused by Rickettsia typhi. The reservoir is in mice and rats, and it is transmitted by the fleas Nosopsyllus fasciatus and Xenopsylla cheopis as well as the rat louse and the tropical rat mite, among these hosts. The insects transmit the disease to man by their infected feces or crushed bodies rubbed into wounds made by the bites. Infection may also result from ingesting rat urine or infected fleas with food.

Malleomyces pseudomallei (Whitmore): This glanders-like disease in Southern Asia which affects rodents and man is transmitted by fleas.

Salmonella typhimurium (Loeffler): Xenopsylla cheopis and Nosopsyllus fasciatus have been found to be naturally infected with Salmonella typhimurium.

Brucella abortus (Schmidt & Weis) (undulent fever): Fleas have been implicated experimentally in the transmission of this disease.

Fleas as the Intermediate Hosts of Helminths

Dipylidium caninum (Linn.) (dog tapeworm). The eggs of this tapeworm are in gested by the larvae of the dog fleas Ctenocephalides canis, the cat flea C. felis or the human flea Pulex irritans. Following ingestion the eggs hatch in the intestinal tract, the larvae migrate through the wall into the body cavity, where they make their way to the muscles, or tissues. They absorb food from the surrounding tissues and mature into cysticercoid larvae. When man swallows an insect, eats beef or hogs, the larva is freed, attaches itself to the intestinal wall, and grows into the mature tapeworm.

In the human this tapeworm is found mostly in children causing nervousness, intestinal disturbances and loss of appetite.

Hymenolepis nana (Siebold) (dwarf tapeworm). Research has shown that the dog flea, rat flea, and human flea are capable of transmitting rat strains of this helminth.

101

The definitive hosts are man, mice and rats. No intermediate host is necessary in its cycle.

Mechanical Injury due to Flea Bites: Many individuals are only slightly affected by flea bites, but in some the resulting skin irritation may be severe. Edematous, raised, roseate lesions may occur which may become pustular and hardened.

Probably the smallest flea known is the famous "jigger," sand flea, or "chigoe" (Tunga penetrans). The chigoe is one of the most annoying pests of tropical and sub-tropical countries where it occurs in immense numbers. The adults are fond of warmth and drought and may be found in dry dust in and about human habitations.
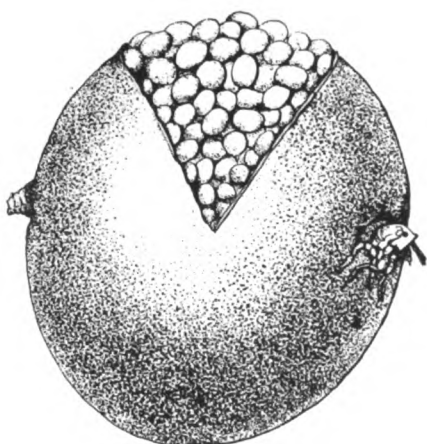
Figure 57
Tunga penetrans distended with eggs

When the female becomes fertilized, she seeks out a suitable host and burrows into the skin, particularly between the toes, under the toenails, and in the tender parts of the feet. Here, nourished by the host's blood, the eggs begin to develop, causing the abdomen to swell almost to the size of a pea. The posterior end of the flea is flush with the surface of the host's skin (Fig. 57). The eggs, as many as 200 in one female, mature and are expelled through the tip of the abdomen; the female then shrivels up and drops out or is expelled by ulceration. A festering itching sore is produced on the skin which normally becomes secondarily infected, ulcerated, and abcessed. The treatment for this flea when embedded in the tissues is not very satisfactory, but each flea may be removed under aseptic conditions by enlarging the opening with a clean needle and carefully removing the entire flea. The wound should then be thoroughly sterilized and dressed.

Humans are infected by contaminated earth, containing eggs which have dropped from pigs or dogs. The larvae are also found on the ground where they feed upon refuse.

Echidnophaga gallinacea (Westwood) (stick-tight flea) is a very common parasite of poultry and wild and domesticated mammals. This flea also attacks man and is very difficult to remove without breaking off the mouth parts.

Classification

The differentiation of genera is based largely on the presence or absence of ctenidia or combs on the head or pronotum, the number of rows of bristles on the abdominal segments, the presence or absence of eyes, the position of the ocular bristle,

102

and many other minor characters. Most species of fleas are normally closely con-
fined to particular kinds of hosts, only a few species being able to thrive on a variety
of them. If the host and geographic locality are known, the number of species to be
considered is comparatively small.

From the medical viewpoint, the fleas of chief interest are those which are com-
monly found on rats and other rodents subject to plague and endemic typhus, and those
which attack man. With this in mind Plate XV. diagrammatically shows how they may
be broken down into three simple groups and gives a representative host upon which
the fleas of each group are often found. A key to the genera of medical importance is
given below.

Key to Some Medically Important Genera of Siphonaptera

1. The three thoracic tergites together shorter than the first
abdominal tergite 2

    The three thoracic tergites together longer than the first
abdominal tergite 3

2. Hind coxa with a patch of small spinules on its inner side .... Echidnophaga

    Hind coxa without patch of spinules on inner side .... Tunga

3. Eyes well developed 4

    Eyes vestigial or absent; both pronotal and genal combs present 10

4. Neither pronotal nor genal combs present 5

    Pronotal comb, at least, present 6

5. Mesopleuron with only one internal rodlike thickening, which
extends from the insertion of the coxa forward to the anterior border.... Pulex

    Mesopleuron with two internal rodlike thickenings, one
extending forward, the other upward .... Xenopsylla

6. Both pronatal and genal combs present 7

    Pronotal comb present but genal comb absent 8

7. Genal comb running horizontally along lower border of gena... Ctenocephalides

    Genal comb running obliquely across gena .... Cediopsylla

8. Third segment of antennal appendage distinctly segmented
both anteriorly and posteriorly 9

    Third segment of antenna distinctly segmented only on the
posterior side .... Hoplopsyllus

9. Labial palpus extending beyond apex of procoxa .... Diamanus

    Labial palpus not reaching apex of procoxa..................... Nosopsyllus

10. Posterior edge of the tibiae with about eight short and several
long bristles, which do not resemble a comb .... Ctenophthalmus

     Posterior edge of tibiae with about twelve short and three
long bristles, the short bristles forming a sort of comb .... Leptopsylla

PLATE XV.

PRINCIPAL CHARACTERS FOR IDENTIFYING FLEAS OF MEDICAL IMPORTANCE
FLEAS WITHOUT PRONOTAL AND GENAL COMBS

Ocular bristle below eye

Single mesopleural thickening

Spermatheca of the female

Pulex irritans (human flea)

Ocular bristle in front of and above center of the eye

Y-shaped mesopleural thickening

Spermatheca of the female

Xenopsylla cheopis (rat flea)

(Head pointed) Thoracic segments constricted

(Head squarely angular) Hind coxa with a patch of spines

Echnidnophaga gallinacea (sticktight flea)

Hind coxa without a patch of spines

Tunga penetrans (chigoe, sand flea)

FLEAS WITH PRONOTAL COMBS ONLY

Pronotal comb

Nosopsyllus sp.   Diamanus sp.

(rodent fleas: squirrels, rats)

FLEAS WITH PRONOTAL AND GENAL COMBS

a. WITH EYES

Genal comb

Ctenocephalides sp. (dog & cat flea)

b. WITHOUT EYES

Leptopsylla sp. (rodent fleas: mice, rats)

105

PLATE XVI.
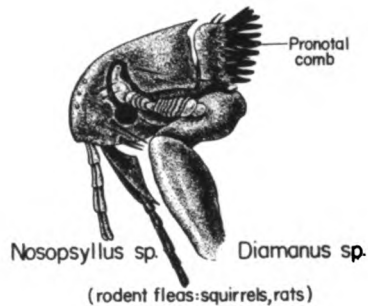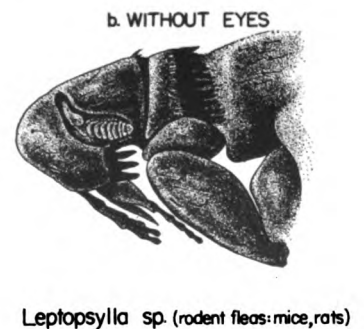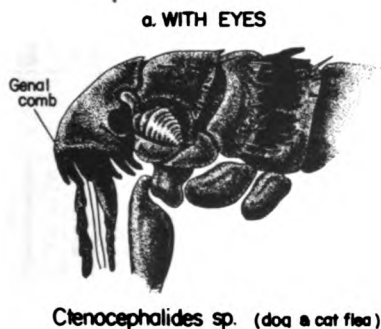
PICTORIAL KEY TO SOME COMMON FLEAS IN THE UNITED STATES

PLATE XVII.

PICTORIAL KEY TO FLEAS FOUND ON DOMESTIC RATS IN SOUTHERN UNITED STATES

Slightly revised April 1947
By Roy F Fritz and Harry D Pratt

No combs present
- Thorax contracted Front margin of head angular — *ECHIDNOPHAGA GALLINACEA*
- Thorax normal Front margin of head rounded
  - 2 rows of bristles on typical abdominal segment — *RHOPALOPSYLLUS GWYNI*
  - 1 row of bristles on typical abdominal segment
    - Mesopleuron divided by vertical rodlike sclerotization. — Ocular bristle inserted in front of eye — *XENOPSYLLA CHEOPIS*
    - Mesopleuron not divided by vertical sclerotization. RECEPTACULUM SEMINIS — Ocular bristle inserted below eye — *PULEX IRRITANS*
    - MESOPLEURON

Pronotal comb present
- 2 rows of bristles on typical abdominal segment
  - Labial palps extending beyond trochanter of first pair of legs — *DIAMANUS MONTANUS*
  - Labial palps not extending beyond trochanter of legs — LABIAL PALP — TROCHANTER
    - Segment 5 of hind tarsi with 1 pair ventral (basal) and 4 pairs lateral plantar bristles — *ORCHOPEAS WICKHAMI*
    - Segment 5 of hind tarsi with 5 pairs lateral plantar bristles — PLANTAR BRISTLES — *NOSOPSYLLUS FASCIATUS*
- 1 row of bristles on typical abdominal segment — *HOPLOPSYLLUS AFFINIS*

Genal and pronotal combs present
- Eye absent or reduced Genal comb of two to four spines.
  - Genal comb with 2 spines — *EPITEDIA WENMANNI*
  - Genal comb with 3 spines — *CTENOPHTHALMUS PSEUDAGYRTES*
  - Genal comb with 4 spines — *LEPTOPSYLLA SEGNIS*

Genal, pronotal and abdominal combs present — *STENOPONIA AMERICANA*
- Eye present. Genal comb of five or more spines.
  - Genal comb vertical Spines blunt — *GEDIOPSYLLA SIMPLEX*
  - Genal comb horizontal Spines pointed
    - Head length twice width
      - Spine I and spine II of genal comb approximately equal in length — *CTENOCEPHALIDES FELIS*
    - Head length not twice width
      - Spine I of genal comb distinctly shorter than spine II — *CTENOCEPHALIDES CANIS*

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107

ORDER HYMENOPTERA
(bees, wasps, ants)

General Characteristics

The insects in the Order Hymenoptera are both winged and wingless. The winged species have <u>four membranous wings</u> with reduced or modified venation. The <u>fore wings are larger than the hind wings</u>. The <u>leading edges of the hind wings are lined with hooks which fasten to the front wings</u>. The <u>females</u> usually <u>possess a sting, piercer or saw on the abdomen</u>. The <u>mouth parts</u> are of the <u>chewing or chewing-lapping type</u>. Metamorphosis is complete.

In the ants (Formicidae) the abdomen is furnished with a pedicel which consists of one or two segments and separates the thorax from the abdomen. The pedicel may be nodiform or possess a wart-like scale. The majority of the ants have elbowed antennae. The workers are normally wingless, but the males and queens are furnished with wings.

The mutilid wasps or "velvet ants" resemble the true ants, but the body is often clothed with colored hairs, and the pedicel of the abdomen lacks the wart-like scale. In this group the females are wingless, the males winged.

Geographical Distribution

Cosmopolitan.

Relation to Man

The bees, wasps, hornets and ants are of medical importance because of their venomous stings. The sting mechanism is a modified ovipositor, hence it occurs only in females. There are two types of glands in connection with the sting in most species. In the honey bee, a pair of glands empty through paired ducts that unite before leading into a large venom reservoir. This reservoir narrows to cylindrical form and receives the outlet of an unpaired gland before entering a muscular bulb attached to the sting (Fig. 58).

The sting mechanisms consists of a pair of palps and a dorsal sheath containing vertical ridges which receive and guide a pair of grooved lancets fitted with backward projecting teeth. The sheath, which is barbed distally, and the lancets puncture the skin and secretions from the paired and single glands are forced downward by the muscular bulb into the wound. The venom consists of different compounds including histamine, acetylcholine, 5-hydroxytryptamine, enzymes, and protein-like substances. Bee, wasp and hornet venoms contain histamine. Wasp and hornet venoms also contain the 5-hydroxytryptamine, and the hornet has acetylcholine as an additional constituent. The venoms apparently originate in the paired glands leading to the venom reservoir. The unpaired gland secretion is thought to have a lubricating function. Efficient stinging organs are found among bees, hornets, wasps and certain of the ants.

108
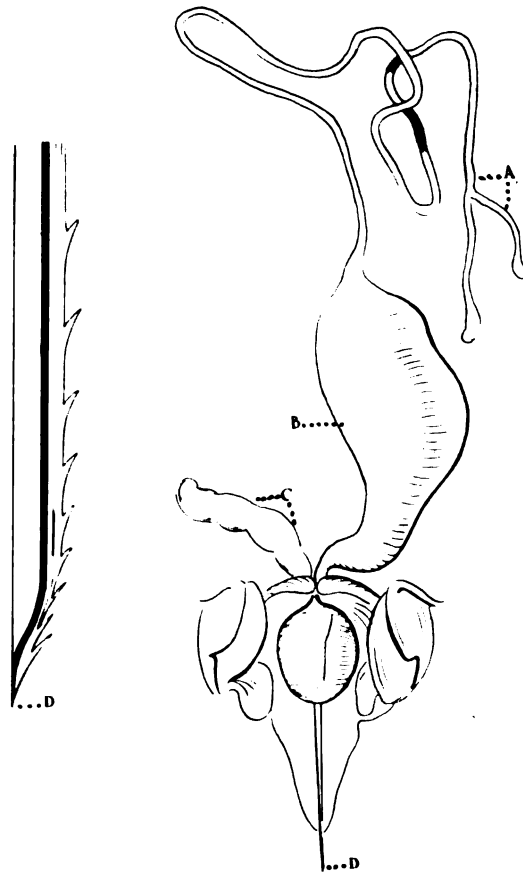
Figure 58
Honey-bee sting. A. Paired venom glands; B. Venom reservoir;
C. Unpaired gland; D. Sting. (Redrawn from Boquet.)

Individuals differ in their reactions to the hymenopteron venom. In many there is little reaction other than a temporary local swelling accompanied by transitory pain. In others there may be systemic symptoms such as weakness and labored breathing, accompanied by severe swelling. Individuals allergic to insect venoms are sometimes affected seriously and death may occur, especially when there are numerous stings.

The pain accompanying ant bites or stings is partly caused by formic acid. These insects cause little damage in the temperate zones, but certain large tropical species cause intense pain and occasional death.

The honey bee loses the tip of the abdomen, and the two poison glands when the barbs of the sting fasten in the flesh. The muscles remain intact and continue to operate the sting, forcing venom past it as it penetrates deeper into the skin. The bumble bees, wasps and ants do not lose their stinging units, and may use them repeatedly.

ORDER DIPTERA
(flies, mosquitoes, gnats, midges)

General Characteristics

To this order belong vectors of some of the most important diseases of man -- malaria, yellow fever, dengue, filariasis, and African sleeping sickness. The members of this order possess <u>one pair of functional wings</u> and rudiments of a second pair present in the form of short, knobbed organs known as <u>halteres</u>. All DIPTERA have complete metamorphosis. The larvae are legless and often wormlike, and not infrequently they are found in the tissues or cavities of man, causing myiasis. All DIPTERA have <u>sucking mouth parts</u>, of which two general types may be recognized, <u>biting</u> and <u>nonbiting</u>. Any dipterous insect possessing mouth parts capable of piercing the skin of man must be regarded as a potential vector of blood-inhabiting, pathogenic micro-organisms; on the other hand, insects with nonbiting mouth parts obviously cannot be responsible for introducing infection directly into the body except through previously injured surfaces. Thus, by inspection of mouth part structure alone, one may estimate the disease-conveying potentialities of any dipterous insect.

The accompaning illustration (Plate XVIII) shows three varieties ot the biting type, (A), (B), and (C), with the various structures dissected out. Normally, in the bladelike type (A) only two prominent structures are visible, the <u>labium</u> and the <u>maxillary palps</u>. The labium ensheathes the piercing and cutting mouth parts which consist of a pair of <u>mandibles</u>, a pair of <u>maxillae</u> (flat, bladelike, and capable of lacerating), and two unpaired, lancetlike organs, the <u>labrum</u> and <u>hypopharynx</u>, also capable of piercing. The approximation of the labrum and the mandibles forms a food canal up which blood is drawn. The salivary secretions are poured out through a duct in the hypopharynx. The maxillary palps are sensory in function and do not serve as cutting organs. This bladelike type is found in the families TABANIDAE, PSYCHODIDAE, CERATOPOGONIDAE, and SIMULIIDAE.

Similar cutting and piercing organs are contained in the labium of the stylet type (B), except in this case the parts are long and slender and capable of particularly deep penetration. Normally, one sees only the maxillary palps and the long, rounded labium, this latter together with the enclosed parts being known as the <u>proboscis</u>. The labium does not take part in cutting in either type A or B. Mosquitoes are common examples of the stylet type.

In type (C), the labium holds in a "labial groove" only the labrum and hypopharynx; maxillae and mandibles are absent. In this case, the labium enters the wound and functions as an efficient piercing organ. The tsetse fly, stable fly, and horn fly have this type of piercing mouth parts. All three types illustrated are mouth parts of <u>females</u>. In many genera, similar structures in males are reduced and are unable to carry on the blood-sucking function.

110

In the nonbiting type (D), the labium is a thick, fleshy appendage enclosing a labrum and a hypopharynx, neither of which is capable of cutting. The fleshy padlike labellum merely acts as a "lapping" or "sponging" organ and is highly efficient in the mechanical transfer of pathogenic organisms.

For purposes of convenience in identification, DIPTERA are grouped here into three suborders distinguishable by the antennal characters of the adults:

1. Suborder ATHERICERA (Cyclorrhapha) includes the common house fly and related flies. Some are important in the mechanical transmission of disease, and the larvae of many are myiasis-producing. Others are vicious biters and pests of man. One genus, Glossina, contains the vector of African sleeping sickness. The antennae of the ATHERICERA are generally three-segmented. The first two segments are short and may be seen only on very close inspection. The third is much larger and bears an arista, a bristle or featherlike structure, on its dorsal surface. This arista taken in combination with the frontal suture is characteristic of the ATHERICERA (Fig. 59). The palpi are single segmented.

Arista with
hairs dorsally
and ventrally

Arista
spine like
and bare

Frontal
suture
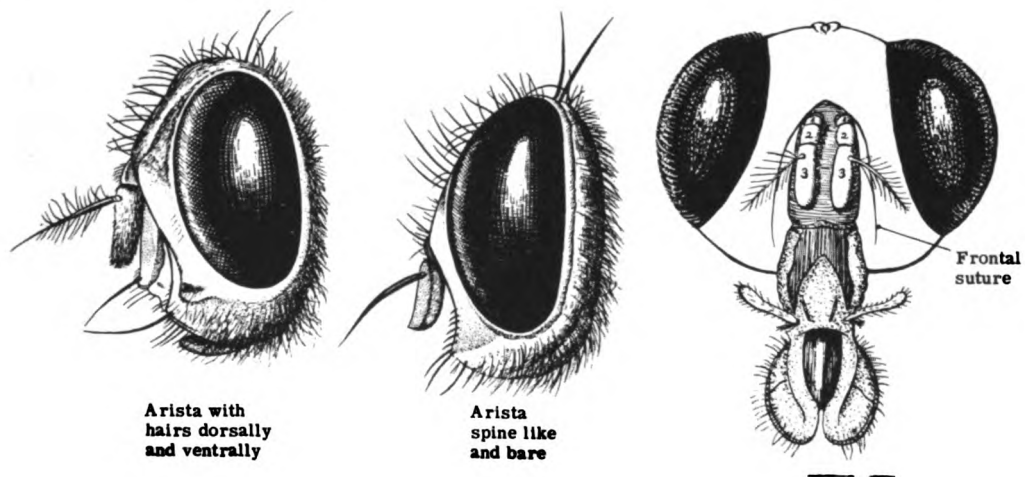
Figure 59.
Antennal characters of the suborder ATHERICERA

2. Suborder BRACHYCERA includes the horse flies and deer flies. One bloodsucking genus, Chrysops, includes vectors of tularemia, a bacterial disease, and loaiasis, a filarial disease. The remainder are important to man only as pests; many are nonbloodsuckers. The BRACHYCERA may be recognized by their three-jointed antennae which are variously formed and usually held horizontally erect. The last segment may be ringed to form several smaller units (Fig. 60). The palpi are one or two-segmented.

3. Suborder NEMATOCERA includes mosquitoes, moth flies, midges, and gnats. Many members of these groups are disease vectors. All NEMATOCERA which transmit disease have biting mouth parts and are blood-sucking forms. Their antennae have

111

1   2   3a

TABANUS

Antennae 3-segmented
3rd. segment elongate -
appearing as several
separate segments.

1   2   3a   b c d e

CHRYSOPS
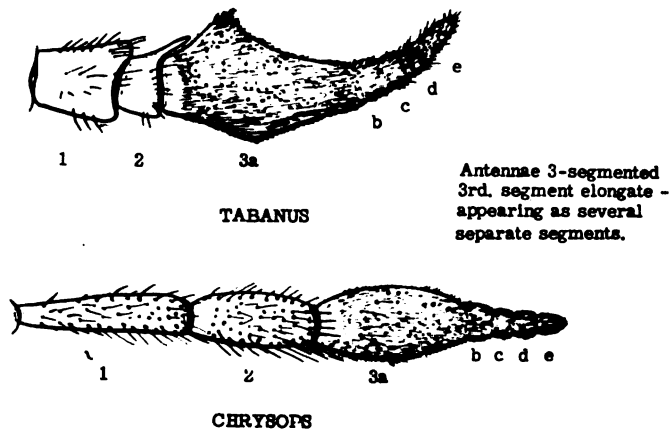
Figure 60.
Antennal characters of the suborder BRACHYCERA

<u>many segments; each segment is similar and approximately of equal diameter</u> through-
out its length, often quite long, longer than the length of the head and thorax toegether.
There is <u>no arista</u> or frontal suture, and the palpi are 4 to 5 segmented (Fig. 61).

Antennae long........composed of
many similar segments

Antennae short........composed of
many similar segments

Figure 61.
Antennal characters of the suborder NEMATOCERA

PLATE XVIII

TYPICAL MOUTH PARTS OF
MEDICALLY IMPORTANT DIPTERA

antenna

maxillary palps

labium

labrum

mandible

hypopharynx

labellum

maxilla

(A) BLADE-LIKE TYPE
CHRYSOPS

labium

hypopharynx

labellum

(B) STYLET TYPE
AEDES, CULEX

arista of
antenna

maxillary palps

labium

labrum

hypopharynx

labellum

labium

(C) LABIUM-PIERCING TYPE
GLOSSINA

(D)   NON-PIERCING TYPE
MUSCA   SARCOPHAGA
LUCILIA   CALLIPHORA

113

PLATE XIX.

PRINCIPAL CHARACTERS FOR IDENTIFYING IMPORTANT
BLOOD- SUCKING DIPTERA

PROBOSCIS ELONGATED

SCALES ON VEINS AND POSTERIOR MARGIN OF WINGS

FAMILY : *CULICIDAE*
(true mosquitoes)

ANTENNAE PROJECTING FORWARD...... THIRD SEGMENT RINGED

WING MEMBRANE ORNAMENTED

SPURS ON HIND TIBIA

FAMILY : *TABANIDAE*
Genus: Chrysops
(deer flies , mango flies)

ANTENNAE SHORT; THREE SEGMENTED ARISTA PRESENT ON BASE OF THIRD SEGMENT

MUSCOID FLIES

ANTENNAE LONG 15 SEGMENTS

WING MEMBRANE ORNAMENTED WITH DARK AND CLEAR AREAS

FAMILY : *HELEIDAE*
(biting midges , punkies)

OVAL WINGS CARRIED ERECT

WINGS AND BODY EXTREMELY HAIRY

PALPS LONG AND RECURVED

ANTENNAE LONG 16 SEGMENTS

FAMILY : *PSYCHODIDAE*
Genus: Phlebotomus
(sand flies , moth flies)

WINGS BROAD, DEVOID OF SCALES AND HAIRS........ANTERIOR VEINS WELL DEVELOPED

THORAX WITH "HUMPBACK" APPEARANCE

ANTENNAE SHORT 10-11 SEGMENTS

FAMILY : *SIMULIIDAE*
(buffalo gnats , black flies)

114

PLATE XX.

PICTORIAL KEY TO PRINCIPAL FAMILIES OF DIPTERA OF PUBLIC HEALTH IMPORTANCE

Antennae of 3 segments or the apical segments more or less fused

Antennae of IO or more distinct segments, usually elongate

4 or 5 posterior cells

Not more than 3 posterior cells (Antennae 3 segmented)

Antennae short, of IO-II segments. Posterior veins fine

Antennae I2-I6 segmented, elongate. Posterior veins not unusually fine

SIMULIIDAE

3rd vein with 3A long, 3B ending behind wing tip

3rd vein with 3A short, 3B ending before wing tip

A. Costa ending before wing tip.
B. Wing veins reduced.
C. Vestiture of wing very sparse.
— COSTA

Wing with costa continued around apex and veins numerous, thickly clad with hairs or scales
COSTA

Abdomen flattened - *TABANIDAE*
Abdomen cylindrical - *RHAGIONIDAE*

STRATIOMYIDAE

HELEIDAE (=CERATOPOGONIDAE)

A. 2nd antennal segment with seam.
B. Mesonotal suture complete

A. 2nd antennal segment without seam.
B. Mesonotal suture incomplete or absent

Wing with cross veins at about the middle

Wing without cross veins beyond the basal third

CULICIDAE

PSYCHODIDAE

Hypopleura bare, or with sparse, fine hairs

Hypopleura with a row of strong bristles

Hypopleura with long, usually dense hairs. Mouthparts vestigial

Oral vibrissae usually present. (Small flies rarely retained by a I6-mesh screen)

Oral vibrissae absent. (Size usually larger, or with prominent ovipositor in female)

Postscutellum undeveloped
CUTEREBRIDAE
Postscutellum large, swollen (See fig. for *TACHINIDAE* below)
OESTRIDAE

MUSCIDAE

(Spurious vein absent. Anal cell not nearly reaching margin of wing)

Postscutellum undeveloped

Postscutellum large, swollen

A. Spurious vein present.
B. Anal cell nearly reaches wing margin.

A. Anal cell short.
B. Female ovipositor prominent

Anal cell absent

LARVAEVORIDAE (=TACHINIDAE)

SYRPHIDAE

EPHYDRIDAE

Usually four notopleural bristles

Only two notopleural bristles

(Mouthparts well developed, functional)

Clypeus broad

Clypeus narrow (Body shining black)

Mouthparts vestigial

SARCOPHAGIDAE

CALLIPHORIDAE

OTITIDAE (=ORTALIDAE)

LONCHAEIDAE

GASTEROPHILIDAE

Body dull to moderately shining

Body strongly shining, usually black

(Antennae apparently 2-segmented. Palpi not large and bristly. Posterior veins strong, with cross veins)

(Wing vein 5 without slight irregularity. Anal vein present)

A. Antennae apparently I-segmented.
B. Palpi large, bristly.
C. Posterior veins fine, without cross veins

A. Mouthparts thick, fleshy.
B. Ist hind tarsal segment broad

A. Mouthparts not thick and fleshy.
B. Ist hind tarsal segment long, slender

A. Vein 5 with slight irregularity.
B. Anal vein absent

A. Abdomen broad basally.
B. Front leg only slightly shorter than hind leg.

A. Abdomen tapered basally.
B. Front leg usually much shorter than hind leg

PHORIDAE

BORBORIDAE

DROSOPHILIDAE

CHLOROPIDAE

PIOPHILIDAE

SEPSIDAE

DHEW-ATLANTA, GA.

IDENTIFICATION OF MEDICALLY IMPORTANT FAMILIES
OF THE ORDER DIPTERA

Included in the three suborders of the order DIPTERA are several families of medical interest. The suborder ATHERICERA includes a miscellaneous group of families, most of which are commonly referred to as the "muscoid flies." The medically important members of this group will be referred directly to genera to avoid unnecessarily complicating the discussion. The suborder BRACHYCERA includes only one family of particular medical importance; the suborder NEMATOCERA, four.

The method of identifying these families is given in the key to medically important DIPTERA. First, the suborders are separated out by the antennal characters; then the families, by the characters illustrated in Plate XIX.

Key to Medically Important DIPTERA

1. Antennae variable, usually long, threadlike, many
   segmented, majority of segments usually alike;
   arista absent ....(suborder NEMATOCERA)................. 2

   Antennae short, three-segmented 5

2. Wings with scales; mouth parts as long as head
   and thorax ....(in part) CULICIDAE

   Wings without scales, mouth parts short 3

3. Wings and body extremely hairy .... PSYCHODIDAE

   Wings and body sparsely haired 4

4. Wings broad, anterior veins well developed; thorax
   humpbacked ....SIMULIIDAE

   Wings and veins of normal size, membrane ornamented
   with dark and light areas; thorax not humpbacked ....HELEIDAE

5. Arista present on base of third antennal
   segment ....(suborder ATHERICERA)......MUSCOID FLIES

   Arista absent; antennae held horizontally erect,
   terminal segment elongate.......(suborder BRACHYCERA)........TABANIDAE

SUBORDER ATHERICERA
(muscoid flies)

Relation to Man

Only one genus, Glossina, is known to be a true biological vector of a human disease, African sleeping sickness. The other genera are chiefly important as mechanical carriers of such diseases as typhoid fever, cholera, and bacillary and amebic dysentery. In a large number of genera the larvae may be internal parasites of man, producing a condition known as myiasis. Because of the great diversity in form and medical importance, we have divided the various genera of the muscoid flies into three small groups:

1. The biting group includes the genera Glossina, Stomoxys, and Siphona (=Haematobia). These blood-sucking flies have biting mouth parts with the proboscis projecting well beyond the head. They are true or potential vectors of disease and usually vicious biters (Fig. 62).

2. The nonbiting include the genera Musca, Fannia, Hippelates, Sarcophaga, Calliphora, and Lucilia. These flies have fleshy, lapping, nonbiting mouth parts, and their living and feeding habits are such as to enable them to inoculate man mechanically, through his food or mucous membranes, with the bacterial and protozoal filth of feces, disease exudates, and decomposing organic matter.

3. The flies whose larvae are occasional or habitual parasites of man include species of the genera Musca, Fannia, Lucilia, Callitroga, Chrysomyia, Sarcophaga, Cordylobia, Auchmeromyia, Dermatobia, and Calliphora. These larvae invade the intestines, the nasal openings and associated sinuses, and the subdermal and muscular tissues of man. Such an infestation of tissues or body spaces by flies is referred to as myiasis. The adults of these flies, with rare exceptions, have nonbiting mouth parts.

Arista feathered

Long maxillary palpus

Short maxillary palpus

Long maxillary palpus

(A) Stomoxys

(B) Siphona

(C) Glossina
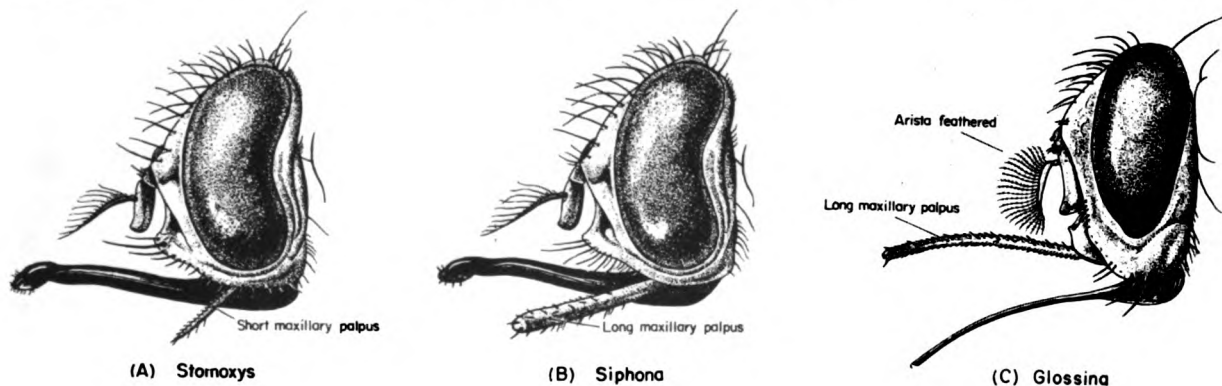
Figure 62.
Heads of important biting muscoid flies

GROUP 1. THE BITING MUSCOID FLIES

Key to the Important Biting Muscoid Flies

1. Palpi short .... **Stomoxys**

   Palpi long 2

2. Hairs on dorsal surface of arista unbranched .... **Siphona**

   Hairs on dorsal surface of arista branched and featherlike .... **Glossina**

Glossina -- the Tsetse Fly

General Characteristics

The tsetse fly may be distinguished from all other flies by the slender, forward-projecting proboscis; its spiny, long, slender palpi; the feathered hairs on the dorsal side of the antennal arista; and the characteristic discal cell (meat cleaver) in the wing (Fig. 63). When at rest the fly folds its wings above the abdomen in scissors fashion.

Geographical Distribution

Tsetse flies occur only in Tropical Africa with the exception of the species tachinoides found also in Southern Arabia. On the African Continent they do not occur in Egypt, Tunis, Algeria, Libya, or Morocco.

"Cleaver" cell
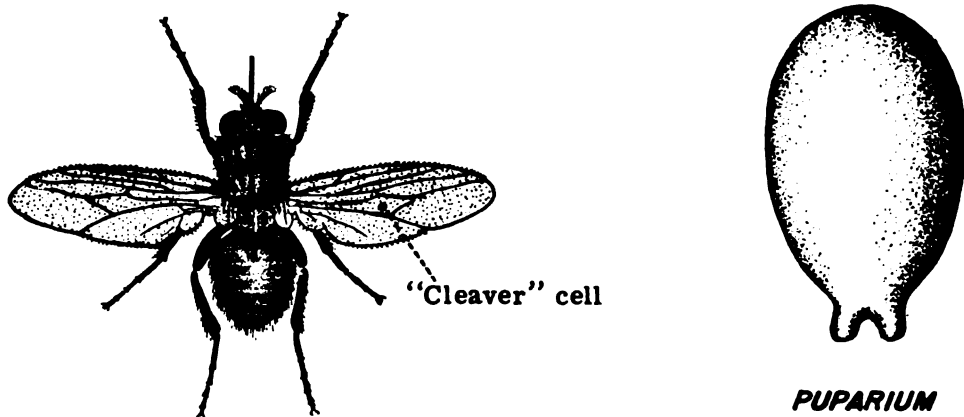
PUPARIUM

Figure 63.
Glossina. Adult tsetse fly and puparium

118

Life Cycle and Habits

The female tsetse fly nourishes her young on intra-uterine milk glands and produces one full-grown larva each 10 or 12 days during her lifetime of 4 or more months. The larvae burrow into coarse sand or other loose soil, moss or rubbish and pupate within an hour after birth. The pupae, which have very characteristic posterior lobes, require about 3 weeks for their development (Fig. 63).

The preferred food of some of the species of medical importance is reptile blood; of others, the blood of game animals. The flies are diurnal feeders. They prefer dark or brown skins to light ones and have been caught in large numbers on black cloths smeared with "tanglefoot." Both sexes feed on blood. They are restricted to certain characteristic "fly-belts;" the type of area infested varies with the species.

Normally, tsetse flies feed in the open areas and breed in thickets, brush or forest canopy. Glossina palpalis (R & D) prefers to breed along the lakes and rivers of West Africa and the Congo in the dense undergrowth of the tropical rain-forest belt in shade and humidity. It feeds on reptiles but can live on warm blooded animals.

On the plains and glades of open country in the Belgian Congo, the Sudan and Rhodesia, Glossina morsitans Westwood becomes the important species. It feeds by preference on game animals in the open savanna with rocky areas containing logs or tree rot-holes as breeding grounds.

Glossina swynnertoni Austen in East Africa breeds in very dry thickets and rocky areas, utilizing open sections as feeding grounds. It lives on game animals but will also attack man.

Relation to Man

Among the biting flies, the tsetses rank second only to the mosquitoes as vectors of human disease. They are the essential biological vectors of the trypanosomes of Gambian and Rhodesian sleeping sicknesses. These diseases are widely distributed throughout Central Africa and took the lives of a half million natives from 1896 to 1906. There are about 25 species of tsetse flies, of which only a few are of primary importance in human disease.

Trypanosoma gambiense Dutton causing Gambian sleeping sickness is found in West Africa and T. rhodesiense Stephens and Fantham, the organisms of Rhodesian sleeping sickness, in East Africa. The trypanosomes undergo approximately 20 days of cyclo-propagative development in the tsetse fly, passing from the mid gut to the salivary glands during this period. They pass to animals or man with the saliva during the bite of the fly, the fly remaining infective for at least three months thereafter. In man there is an incubation period of ten days to three weeks, but this may be delayed. Numerous species of wild mammals harbor the trypanosomes in nature, forming a reservoir of the disease.

119

Stomoxys -- The Stable Fly or Dog Fly

General Characteristics

This genus has several species, but the stable fly or dog fly, Stomoxys calcitrans (Linn.),is the best known, resembling the house fly rather closely. It is sometimes referred to as the "biting house fly," but can readily be distinguished by its slender, forward projecting, biting proboscis, and the antennal arista with hairs on the dorsal side only (Plate XXI).

Geographical Distribution

Cosmopolitan.

Life Cycle and Habits

Stomoxys calcitrans breeds in moist, rotting and fermenting vegetable matter such as hay, grass, marine grass, grain, or horse manure. The female lays her eggs deep in the fermenting material, 25 to 50 at a time, totaling several hundred. After about three days these hatch, and the larvae begin feeding upon the surrounding vegetable matter. The larvae resemble those of the house fly but differ in the location of the posterior spiracles, and in form and size. The posterior spiracles, situated near the outside, are well separated and triangular in shape. The larvae mature in two or three weeks, pupate in the drier material, remain for another week to three weeks, and emerge as adults. The adults are long lived and strong fliers.

Relation to Man

Although Stomoxys has been frequently used in experimental transmission of disease, there is no conclusive evidence that it is a natural vector. However, because of its blood sucking habits, it will always be regarded as a potential vector. The mechanical transmission of such diseases as poliomyelitis, yellow fever, tetanus and anthrax by this species is a possibility, but the transfer of organisms probably would require blood meals on two hosts in succession rather than the second meal after a long delay. Surra of horses, a trypanosomiasis, is mechanically transmitted in nature by species of Stomoxys. Experimentally it has been found capable of the transmission of Trypanosoma gambiense, T. rhodesiense, and Leishmania tropica.

The males and females are capable of inflicting a very painful bite by puncturing the skin, roughly inserting the mouth parts, and sucking blood. They are daytime feeders. The female requires at least three blood meals before oviposition occurs. Their normal hosts are horses, cattle, man, monkeys, rabbits, guinea pigs, and rats.

Siphona (Haematobia) -- The Horn Fly

General Characteristics

This insect was originally found in Europe where it was a cattle pest, and was introduced into the United States in 1887. It closely resembles the house fly in appearance and wing venation, but is only about half its size. It resembles Stomoxys in its mouth parts, except that the palpi are almost as long as the proboscis, and the hairs on the arista of the antennae are on both the dorsal and ventral sides. The horn fly is a day feeder, resting on the animal's horns frequently, particularly at night.

Geographical Distribution

Species of Siphona are confined to the Old World with the exception of the species introduced to the United States.

Life Cycle and Habits

The horn fly prefers freshly deposited cow dung in which to lay its eggs. The larvae make their way into the dung and mature in three to five days. They pupate beneath the manure and emerge as adults in about a week, the life cycle requiring 10 days to 2 weeks for completion.

Relation to Man

The horn fly rarely attacks man, but because of its blood-sucking habits will always be regarded with suspicion as far as disease transmission is concerned. It is an irritating and annoying pest of cattle, causing loss of weight and milk production. They often become very numerous on these animals.

GROUP 2. THE NON-BITING MUSCOID FLIES

Musca domestica Linn. -- The Common House Fly

General Characteristics

The house fly has four dark, longitudinal stripes on the thorax and a dark central area on the abdomen. The mouth parts are not sharply pointed as in the stable fly (Stomoxys), and are of the type illustrated in Plate XVIII, Fig. D. The pad-shaped tip of the non-biting, sponging mouth parts is a convenient mechanism for mechanical transfer of pathogenic organisms from infected material to healthy individuals. The antennae extend downward, are recessed in the face, and contain dorsal aristae which are plumose to the tips. Vein four in the wing makes a sharp bend forward. The common latrine fly (Fannia scalaris (Fabr.) is often mistaken for the house fly, but an examination of the wings and antennae will differentiate the two.

Geographical Distribution

Cosmopolitan. <u>Musca</u> <u>domestica</u> gives way to different varieties in various parts of the world. In Egypt and India <u>Musca</u> <u>domestica</u> <u>vicina</u> Macq. replaces it. <u>Musca</u> <u>nebulo</u> Wied. is present in India. <u>Musca</u> <u>sorbens</u> Wied. is found in Egypt, Ethiopia, and Indonesia.

Life Cycle and Habits

<u>Egg</u>: The eggs of the house fly are laid in masses of about 75 to 150. A single female is able to lay as many as 21 such batches in the month after emergence. Excrement, especially that of horses, is a favorite breeding material. Cattle, hog, chicken, and human feces are also used by flies for breeding. The fact that they breed readily in human excrement makes them especially dangerous as disease carriers. Other suitable materials include garbage, kitchen refuse, and other decomposing vegetable and animal matter.

<u>Larva</u>: Hatching takes place in about 20 hours under warm summer conditions, and the slender, white, legless maggot completes its development in about 5 days.

<u>Pupa</u>: After the maggot attains its full growth, it migrates to drier parts of its habitat and changes to a pupa within the smooth, dark brown, barrel-shaped puparium, a covering formed by the last larval skin which is not shed. The pupal stage requires about 4 days, making a total of about 10 days from egg to adult insect.

<u>Adult</u>: Successive broods of flies follow each other throughout the summer, resulting in a great increase toward autumn. Their reproductive ability can best be illustrated by the following: A pair of flies at the beginning of the breeding season may be the progenitors, if all were to live, of 191,000,000,000,000,000,000, offspring by August. Allowing one-eighth of a cubic inch to each fly, this number would cover the earth to a depth of 47 feet.

A very practical problem in the relation of house flies to disease is the extent to which they may scatter from their breeding places. As a rule, most flies will not travel more than a quarter of a mile in thickly settled areas, but a maximum distance of 13 miles has been reported. Some house flies have been recovered 6 miles from the point of their release in less than 24 hours.

Relation to Man

The house fly and many of its relatives are common agents in the mechanical transmission of certain infections which are often grouped under the term, "flyborne diseases." The mouth parts, the numerous body spines, and the sticky pads on the feet have been found to carry a large number of different pathogens causing

human disease. Some of these pathogens may pass unaltered through the digestive tract and may remain viable in the feces or "fly specks." Among the pathogens carried mechanically by the house fly are included those causing typhoid fever, cholera, bacillary and amebic dysentery, tuberculosis, tetanus, anthrax, leprosy, bubonic plague, yaws, conjunctivities, trachoma, erysipelas, gonorrhea, septicemia, abscesses, and gangrene. Over 30 different diseases have been shown to be transmitted by the house fly.

From the disease viewpoint, it should be emphasized that from feeding on excrement, sputum, open sores, or putrefying matter, the flies may quickly pass to food or milk, to healthy mucous membranes, or to uncontaminated wounds. It is these filthy habits that make this fly and related forms such dangerous mechanical vectors of disease.

The method of feeding has an important bearing on the house fly's ability to transmit disease organisms. When feeding, the fly frequently moistens substances with a "vomit drop" which is regurgitated from the crop. This vomit drop dissolves solid materials to be used as food, and most of the material is sucked up again. The vomit drop may be teeming with typhoid and cholera bacilli, or with the organisms causing amebic or bacillary dysentery, which are thus transferred to food and milk. In the same manner, the spirochaetes of yaws may be transferred by flies feeding on the ulcer and then on scratches or skin abrasions of healthy individuals. The causative agents of trachoma may be spread by flies feeding on infective matter in the eyes of patients or on soiled bandages.

The larvae often contain organisms they have ingested due to their feeding habits. These are carried forward through the pupal stage into the adult, and may be disseminated by the latter. The spores of tetanus, anthrax, and the eggs of Ascaris are thought to be transmitted in this fashion.

Adult flies may also ingest the eggs of certain parasitic worms such as Ascaris, whipworm, and other roundworms while feeding on feces. They have been found to harbor the eggs of Enterobius vermicularis (Oxyuris), Ascaris lumbricoides, Trichuris trichiura, Ancylostoma duodenale, Taenia solium Linn., Dipylidium caninum (Linn.), and Echinococcus granulosis (Batsch.). There is very little chance that flies are responsible for transmitting infections by such helminths, since they usually require a secondary host, or considerable time, before reaching the infective stage. However, it is possible that those helminths that develop without an intermediate host, and others that can develop to the infective stage in man, might rarely be disseminated by the house fly.

123

Hippelates -- The Eye Gnat

General Characteristics

Hippelates is small in size and usually has a dark body with the underside of the abdomen and legs yellow. The antennae are characteristic; the third segment is almost globular and the arista bare. There is a distinct, curved, shining, black, apical or subapical spine on the hind tibia (Fig. 64).

Geographical Distribution

Species of eye gnats have been associated with disease in the United States (California, Florida and Georgia), Jamaica, Cuba, Colombia, and other places in the American Tropics.

Life Cycle and Habits

The eggs are deposited on a wide range of decaying organic matter, including excrement; provided the material is rather loose, mixed with soil, and well aerated. Evidently, they will not develop naturally in closely compacted soil or putrid material, or in excrement unless it is mixed with loose earth. The larvae require about 11 days for their development. Pupation takes place close to the surface of the material in which the larvae develop. The pupal stage lasts about 6 days, making a total of about 3 weeks for the completion of the life cycle.

Relation to Man

These small flies show extraordinary persistence in returning to feed on lachrymal secretions even though brushed away continuously. This habit has given them the name of "eye gnats" or "eye flies." They do not bite, but the spines on the labellum apparently act as a rasping instrument capable of producing multiple lesions which assist in the invasion of pathogenic organisms.
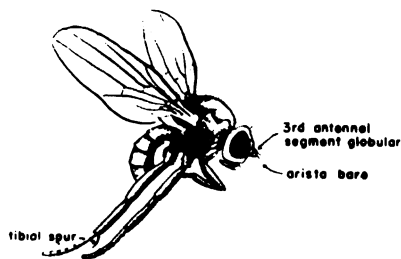
Although the adults do not have piercing mouth parts, they are habitually attracted to the skin and natural orifices of man and animals. Here they lap up lachrymal secretions, sebaceous secretions, pus and blood from wound exudates or from scratches and insect bites.

Figure 64.
Hippelates

The habits of these insects thus render them particularly dangerous as mechanical carriers of eye infections and of various diseases of the skin and mucous membranes. Evidence is available to show that in Jamaica, Hippelates pallipes Loew may be an

124

actual carrier of the organism causing yaws. Enormous numbers of flies have been observed on the ulcerative lesions; and the causative agent, Treponema pertenue Castellani has been found in the anterior gut and stomach of the fly. The spirochaetes survive only about 7 hours in the gut, and it is suggested that the yaws infection is transmitted to another individual by regurgitation of an infected "vomit drop" when the fly feeds on any skin abrasion or ulceration that may be present. It has also been reported that Hippelates flies are important agents in the transmission of catarrhal conjunctivitis or "pink eye," since they are readily attracted by the resulting lachrymal secretions. Experimentally, the disease pinta which is closely related to yaws, and caused by Treponema carateum (Bianco), has been transmitted to man by the Hippelates fly.

Miscellaneous Mechanical Contaminators

In addition to the house fly and eye gnat, a number of other muscoid flies may also play a role as mechanical contaminators. In the tropics, especially in Africa and in certain of the South Pacific islands, closely related species of Musca, similar in appearance and habits to the common house fly, may be important disseminators of intestinal diseases and of yaws. Other genera may also be involved, and some of the more common forms are listed below:

Calliphora	-	the blue bottle fly
Fannia	-	the latrine fly
Lucilia	-	the green bottle fly
Sarcophaga	-	the grey flesh fly

GROUP 3. THE MYIASIS PRODUCING MUSCOID FLIES

Relation to Man

Myiasis is a term applied to the disease produced by fly maggots or larvae when they live parasitically in the organs and tissues of man or animals. Clinically, myiases may be classified according to the part of the body invaded. Thus, when the invasion involves the intestinal tract, it is referred to as "intestinal myiasis;" when it involves the skin, "cutaneous myiasis." Other types are designated as urinary, ophthalmic, auricular, traumatic or nasal myiasis.

The myiasis-producing flies may be grouped according to the degree of insistence displayed by the adult flies in selecting living tissues in which to deposit their young.

1. Obligatory parasites: These larvae invade and develop only in living tissues. Examples:
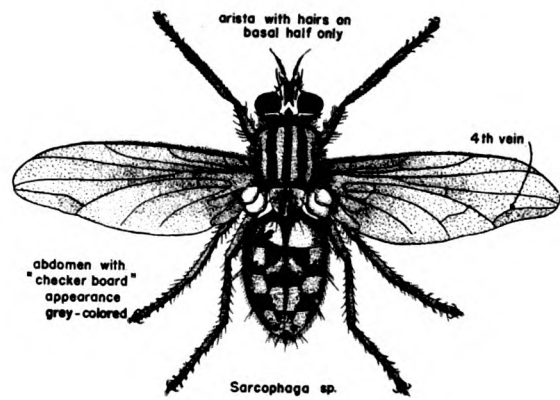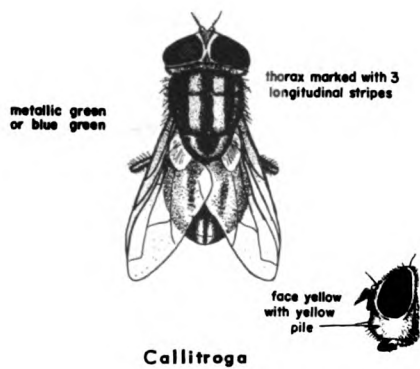   a. Chrysoma bezziana (Villen.), the Old World screw-worm fly, of the Orient and Ethiopia prefers man and animals, infesting open wounds, abscesses, the mouth, nose, conjunctiva, sinuses, or urinogenital passages. In open wounds the larvae

125

Key to the Nonbiting Muscoid Flies

1. Small, usually dark flies; hind tibiae with distinct, curved
   shining black, apical or subapical spur; third antennal segment
   globular, arista bare .... Hippelates

   Medium-sized or large flies 2

2. Grey, yellowish, or dull-colored flies 3

   Blue, metallic green, or blue-green flies 5

3. Bend of fourth vein acute, joining margin of the wing close to
   the third vein; arista with hairs.. 4

   Bend of fourth vein absent, reaching wing margin far below third
   vein; arista bare; anal vein characteristically strongly curved
   forward as if to intersect the sixth vein .... Fannia

4. Frequently large, grey or yellowish colored flies; abdomen with a
   "checkerboard" appearance thorax marked with three dark,
   longitudinal stripes (Plate XXI) .... Sarcophaga

   Medium-sized greyish-black flies; abdomen without "checker-
   board" appearance, thorax marked with two or four dark
   longitudinal stripes (Plate XXI) .... Musca

5. Face yellow with soft yellow pile........................... 6

   Face without yellow pile 7

6. Thorax marked with three longitudinal stripes; lower squama
   without long hairs above; genus of western hemisphere (Plate XIX)..... Callitroga

   Thorax without distinct longitudinal stripes; lower squama with
   long hairs above; genus confined to Africa, Islands of the Pacific,
   including Philippines, Australia, and certain sections of Asia ...... Chrysomyia

7. Base of the first vein with a row of long, distinct hairs on its
   upper surface; dark, metallic blue-black in color, with orange
   anterior spiracle; the "black blowfly" .... Phormia

   Base of the first vein without such hairs; body color bright blue
   or green, at least on the abdomen 8

8. Usually large flies with a whitish sheen over abdomen; lower
   squama with long hair above: bluebottle flies (Plate XXI) .... Calliphora

   Usually flies of moderate size; lower squama without long
   hair above; greenbottle flies (Plate XXI) .... Phaenicia and Lucilia

126

PLATE XXI.

MUSCOID FLIES

Base of Radius

abdomen and thorax
with many long bristles
and hairs.

blue or metallic
blue color

Calliphora sp.

arista with hairs on upper
and lower surface extending
to tip

thoracic stripes

4th
vein

Musca domestica

green or metallic green

thorax unmarked

Lucilia sp.

elongated piercing
proboscis

Stomoxys calcitrans

metallic green
or blue green

thorax marked with 3
longitudinal stripes

face yellow
with yellow
pile

Callitroga

arista with hairs on
basal half only

4th vein

abdomen with
"checker board"
appearance
grey-colored

Sarcophaga sp.

127

produce foul-smelling, mutilated lesions. In the eye or ear they may cause the loss of the organs, and in the nose the entire nares of the nasal cavity may be eroded. They have been known to cause death. The time from egg deposition to larval maturity is in the neighborhood of one to two weeks.

b. Dermatobia hominis (Linn.) of the family Oestridae (warble flies) causes cutaneous myiasis in man and animals in Tropical South America, Central America and Mexico. The warbles are found in herbivorous animals including the skin on the backs of cattle. The adult utilizes some species of insect, such as mosquitoes or biting flies, to transport the eggs to the host, cementing the eggs to the abdomen of the insect. The warmth of the host's body causes the eggs to hatch and they enter the skin either through the opening made by the mouth parts of the insect or directly. They do not move about in the skin, but remain stationary, producing a boil-like swelling with a hole in the top which causes oozing of blood with intense pain. The larvae develop from seven weeks to three months then drop off the host to the ground and pupate. The adult emerges in about three weeks.

c. Hypoderma of the family Oestridae includes the well-known ox warbles found in the skin of cattle and other animals where they cause mounds in the skin similar to boils (warbles). The boils, as with Dermatobia, contain holes through which the larvae breathe. They cause "larval migrans" (creeping eruption) in the skin of man. This genus is found in North America, Europe and Asia. In human infection the eggs are laid on the skin, the larvae penetrate and migrate upward, sometimes practically the length of the body. When the larvae are mature they leave the host and drop to the ground for pupation. The life cycle is long, requiring at least a year.

d. Oestrus of the above family inhabit the nasal cavities and the sinuses of game animals, goats and sheep. They have been found infesting the conjunctiva, mouth and nasal cavities and rarely the ears of man, in Russia, Italy, Palestine and North Africa. The species Oestrus ovis (Linn.) is world wide in distribution. The adults may deposit larvae in the human eye or nasal passages. The larvae cause severe pain as they attach their mouth hooks to the membrane of the conjunctiva. Loss of sight has been known to occur. Pupation is on the ground as in other species. There are two generations a year depending upon the climate.

e. Callitroga (Cochliomyia) americana Cushing & Patton (hominivorax) the primary screw-worm is found throughout the American Tropics, Subtropics and in the Southern United States. This species is not an infrequent cause of traumatic and nasal myiasis in man. The eggs are laid on the skin and the larvae penetrate soon after hatching. They produce deep, festering, often disfiguring wounds and sometimes cause death. Callitroga belongs to the family Calliphoridae. The larvae develop to maturity in one to three weeks. The larvae pupate in the soil and become adults in from a week to two months depending upon the temperatures.

f. Cordylobia anthropophaga (Blanch.) the Timber Fly of Tropical Africa, another of the Calliphoridae, lays its eggs in the dust where humans are likely to

128

sleep. The eggs hatch and the larvae penetrate the skin of their sleeping host. They remain more or less stationary in a swelling resembling a boil, with the usual hole in the top for air. It requires 8 to 10 days for the larvae to mature, after which they emerge through the hole, fall to the ground, bury themselves and pupate. The pupal stage requires from twelve to fourteen days. Natural hosts are wild rodents, dogs, and monkeys.

g. <u>Wohlfahrtia vigil</u> (Walk.), a flesh fly of the family Sarcohpagidae is actually a semi-obligate parasite which frequently causes cutaneous myiasis in young animals and human infants. The larvae appear to be able to penetrate the uninjured skin. It is a New World species.

The females dart suddenly at their hosts and deposit several larvae on the skin usually around the eyelids, cheeks, naval, neck, chest or shoulders. They may migrate some distance before penetrating the skin, but once under the epidermis they cause a small elevated abscess which is open through the surface. When many larvae are involved systemic symptoms such as fever, dehydration, loss of weight, and irritability may occur. In seven to nine days the larvae pupate, the adults appearing approximately eleven days thereafter.

2. <u>Facultative parasites</u>: These maggots normally live in decomposing matter, but the adults may occasionally lay eggs in living tissues, being attracted by foul discharges and blood. Examples:

a. <u>Callitroga</u> (<u>Cochliomyia</u>) <u>macellaria</u> (Fabr.) the secondary screw-worm. This species normally lays its eggs in dead or dying animals. It is sometimes attracted by the foul wounds inhabited by <u>C</u>. <u>americana</u> larvae, and the two species may thus be found together. <u>C</u>. <u>macellaria</u> is found widely distributed in the Western Hemisphere. The incubation period is just a few hours, and the larvae feed upon the rotting flesh. Development of the larvae is also short, requiring only three to six days, after which time they crawl out, burrow into the ground, pupating in two or three days. The pupal period is also around three days. The entire life cycle only requires about twelve days.

b. <u>Lucilia</u> (Calliphoridae) are green bottle flies which include the sheep maggots. These flies usually feed on dead animals, garbage, and excrement. <u>Lucilia sericata</u> (Meig.) completes its entire life history in about 12 days in warm temperatures. The genus has a wide distribution. The female may lay eggs in foul wounds of man or in body openings such as the ear. <u>L</u>. <u>sericata</u> is reported as attacking uninjured tissue in man in China and North Africa. <u>Lucilia cuprina</u> (Wied.) affecting sheep in Australia, causes cutaneous, intestinal and genito-urinary myiasis in man.

c. <u>Calliphora</u>, the common blue bottle or blow fly of the Family Calliphoridae, will not oviposit in clean wounds, but does so readily in foul ones. This genus has world wide distribution and normally lives in cooked and uncooked meats, or decaying

animal and vegetable matter. The life cycle is completed rapidly, the eggs hatching in from eight to twenty-four hours; larval growth requiring four to nine days, and the pupal stage in the ground lasting ten to seventeen days.

d. _Phormia_ (black bottle flies, Calliphoridae). The larvae of the black bottle flies, live in carcases or carrion, over-wintering probably in soil beneath the carcasses or possibly in manure. They are cosmopolitan in distribution. The entire life cycle only takes about three weeks. They occasionally infest pus-producing wounds of man where they feed on moribund flesh, but have the ability to penetrate the skin and have been known to attack healthy tissues.

f. _Sarcophaga_, (grey flesh flies, family Sarcophagidae) may be attracted to foul wounds for larvaposition. Larvae have been found in sores, wounds and natural body openings of man. The larvae are deposited on carrion, mammalian excrement, dead insects, etc. Distribution is world wide. The life history in warm climates ranges from 14 to 18 days depending upon the species. _S. haemorrhoidalis_ (Fall.) causes intestinal myiasis. Larvae of this genus have been taken from cutaneous ulcers, nasal orifices, sinuses, and wounds. _S. fuscicauda_ Böttcher causes traumatic myiasis.

3. _Accidental parasites_: The eggs or larvae of these flies are sometimes swallowed, usually in food or drink. Under such circumstances, the maggots may develop in the intestine, but this development is accidental and not a part of the normal life cycle or the result of any choice on the part of the fly. Examples:
Calliphora, _Sarcophaga_, _Musca_, _Fannia_, _Eristalis_, species of Phoridae, Drosophilidae, and _Stomoxys_.

Note that although the adults of these forms belong almost entirely to the non-biting muscoids, one genus, _Stomoxys_, of the biting group also has larvae which may cause intestinal myiasis.

Identification of Myiasis-Producing Fly Larvae

Maggots, the larvae of the muscoid DIPTERA, are footless, wormlike, and more or less cylindrical. They usually taper anteriorly and are broad and truncate posteriorly, with 11 or 12 distinct segments. At the blunt or posterior end is a pair of stigmal plates. Each plate covers the opening into a breathing tube, or trachea, and is characteristically shaped and perforated to allow the passage of gases. The shape, sculpturing, and position of plates are characters used in the identification of maggots (Plate XXII).
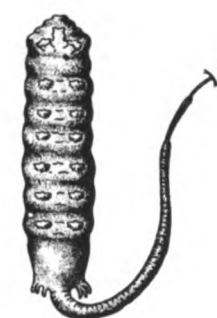
Detailed preparation is not necessary for an examination of the stigmal plates and spiracles. It is sufficient merely to remove a thin slice at the posterior end of the larva and examine it under the low power of the microscope. The following key and its accompanying plate will serve to identify the more common fly larvae concerned in myiasis.
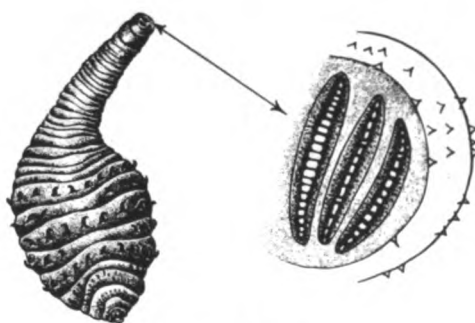
130

Key to the Important Myiasis-Producing Larvae

1. Body with spinous or fleshy processes laterally and dorsally or
   terminally .... **Fannia**

   Body smooth or with short spines, but never with long fleshy
   lateral processes 2

2. Body with a long slender tail or caudal process capable of a certain
   amount of extension and retraction .... **Eristalis**

   Body sometimes narrowed posteriorly, but never with a long
   flexible caudal process 3

3. Larvae more or less grublike; most species slightly flattened dorso-
   ventrally 4

   Larvae maggotlike, or typical "muscoid" shape, tapering anteriorly,
   broadly truncate at the posterior end; cross section more or less
   circular at all points 5

4. Posterior spiracular plate with three distinct slits ....**Dermatobia**

   Posterior spiracular plate with many fine openings .... **Hypoderma**

5. Posterior spiracles with the button area well chitinized and the
   ring complete; spiracles never in a distinct depression 6

   Posterior spiracles with the button very slightly chitinized or absent,
   the ring being incomplete in the button areas 8

6. Button area a part of the ring. slits nearly straight 7

   Button area with the ring slits sinuous, with at least a double curve 9

7. Principal transverse subdivisions of spiracular slits well marked,
   usually not more than six in number; both ring and button heavily chitinized.
   the ring thickened into points at two places between the slits .... **Calliphora**

   Transverse subdivisions of spiracular slits less distinctly marked,
   from 6 to 20 in number; ring and button less heavily chitinized, the
   ring thickened into point at only one place between the slits .... **Lucilia**

8. Posterior spiracles in more or less of a distinct pit or depression,
   vestigial button usually present; integument rather smooth .... **Sarcophaga**

   Posterior spiracles flush with surface integument rather
   spiny .... (Western Hemisphere) ..**Callitroga**

9. Posterior spiracular plates D-shaped; each slit thrown into
   several loops .... **Musca**

   Posterior spiracular plates triangular, with rounded corners;
   spiracular slits S-shaped; button indistinct, centrally placed........ **Stomoxys**

131

PLATE XXII.

BODY STRUCTURE AND STIGMAL PLATES OF SOME
MYIASIS-PRODUCING FLY LARVAE

ANTERIOR SPIRACLE

MOUTH HOOKS

POSTERIOR SPIRACLES
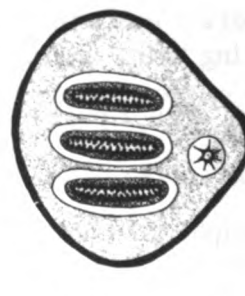(STIGMAL PLATES)

Eristalis
tenax

Dermatobia
hominis

Fannia
scalaris

Musca
domestica

Stomoxys
calcitrans

Hypoderma
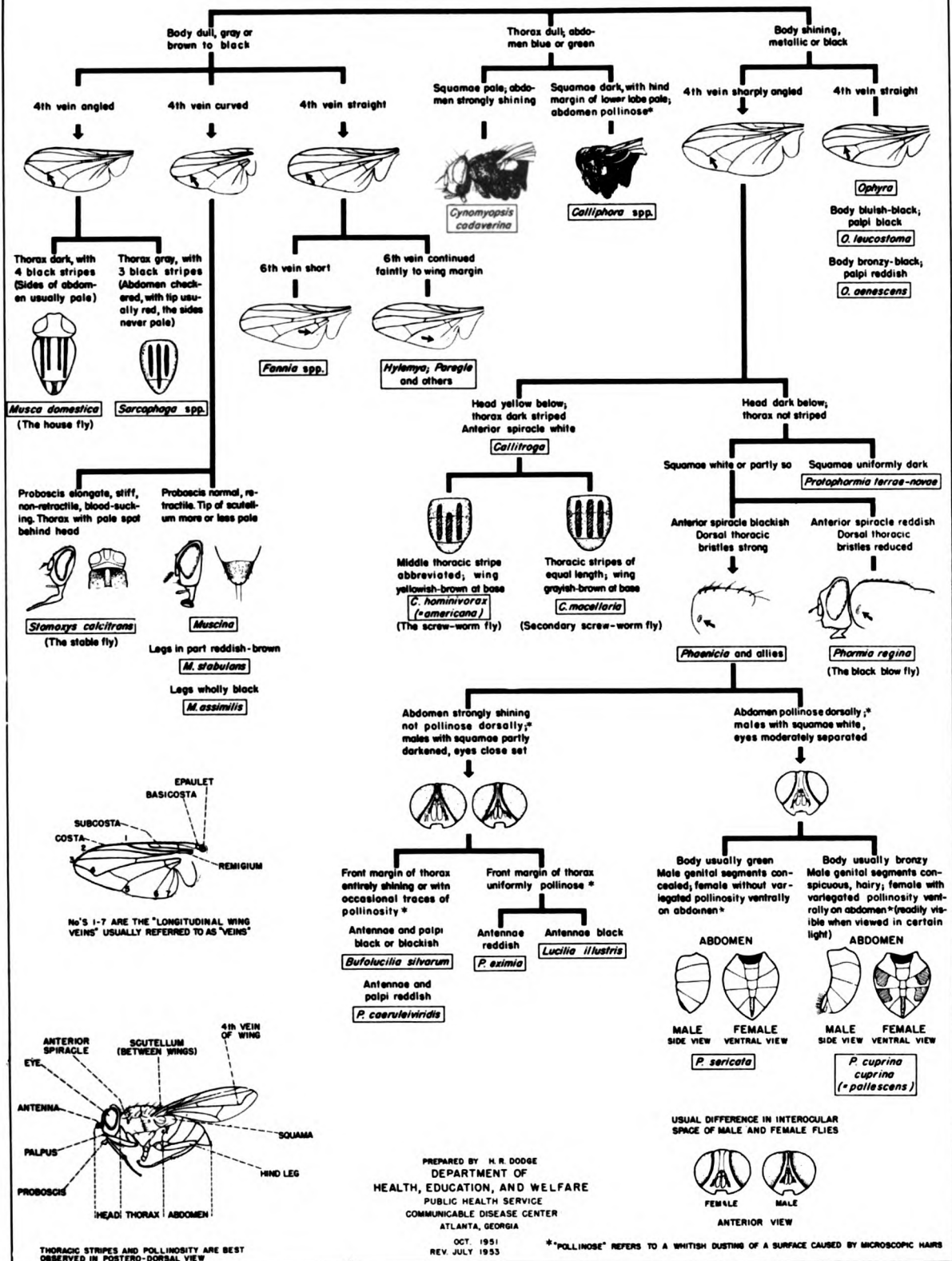lineatum

Auchmeromyia
luteola

Calliphora
sp.

Sarcophaga
sp.

Chrysomyia
sp.

Callitroga
sp.

PLATE XXIII.

PICTORIAL KEY TO COMMON DOMESTIC FLIES IN THE U. S.

Body dull, gray or brown to black

Thorax dull; abdomen blue or green

Body shining, metallic or black

4th vein angled — 4th vein curved — 4th vein straight

Squamae pale; abdomen strongly shining

Squamae dark, with hind margin of lower lobe pale; abdomen pollinose*

Cynomyopsis cadaverina

Calliphora spp.

4th vein sharply angled — 4th vein straight

Ophyra

Body bluish-black; palpi black — *O. leucostoma*

Body bronzy-black; palpi reddish — *O. aenescens*

Thorax dark, with 4 black stripes (Sides of abdomen usually pale)

Thorax gray, with 3 black stripes (Abdomen checkered, with tip usually red, the sides never pale)

6th vein short — 6th vein continued faintly to wing margin

Fannia spp.

Hylemya; Paregle and others

Musca domestica (The house fly)

Sarcophaga spp.

Head yellow below; thorax dark striped Anterior spiracle white — *Callitroga*

Head dark below; thorax not striped

Squamae white or partly so

Squamae uniformly dark — *Protophormia terrae-novae*

Proboscis elongate, stiff, non-retractile, blood-sucking. Thorax with pale spot behind head

Proboscis normal, retractile. Tip of scutellum more or less pale

Stomoxys calcitrans (The stable fly)

Muscina

Legs in part reddish-brown — *M. stabulans*

Legs wholly black — *M. assimilis*

Middle thoracic stripe abbreviated; wing yellowish-brown at base — *C. hominivorax* (=americana) (The screw-worm fly)

Thoracic stripes of equal length; wing grayish-brown at base — *C. macellaria* (Secondary screw-worm fly)

Anterior spiracle blackish Dorsal thoracic bristles strong

Anterior spiracle reddish Dorsal thoracic bristles reduced

Phaenicia and allies

Phormia regina (The black blow fly)

EPAULET / BASICOSTA / SUBCOSTA / COSTA / REMIGIUM

No'S 1-7 ARE THE "LONGITUDINAL WING VEINS" USUALLY REFERRED TO AS "VEINS"

Abdomen strongly shining not pollinose dorsally;* males with squamae partly darkened, eyes close set

Abdomen pollinose dorsally;* males with squamae white, eyes moderately separated

Front margin of thorax entirely shining or with occasional traces of pollinosity*

Antennae and palpi black or blackish — *Bufolucilia silvarum*

Antennae and palpi reddish — *P. caeruleiviridis*

Front margin of thorax uniformly pollinose*

Antennae reddish — *P. eximia*

Antennae black — *Lucilia illustris*

Body usually green Male genital segments concealed; female without variegated pollinosity ventrally on abdomen*

ABDOMEN — MALE SIDE VIEW / FEMALE VENTRAL VIEW — *P. sericata*

Body usually bronzy Male genital segments conspicuous, hairy; female with variegated pollinosity ventrally on abdomen* (readily visible when viewed in certain light)

ABDOMEN — MALE SIDE VIEW / FEMALE VENTRAL VIEW — *P. cuprina cuprina* (=pallescens)

ANTERIOR SPIRACLE / SCUTELLUM (BETWEEN WINGS) / 4th VEIN OF WING / EYE / ANTENNA / SQUAMA / PALPUS / HIND LEG / PROBOSCIS / HEAD THORAX ABDOMEN

USUAL DIFFERENCE IN INTEROCULAR SPACE OF MALE AND FEMALE FLIES

FEMALE / MALE — ANTERIOR VIEW

THORACIC STRIPES AND POLLINOSITY ARE BEST OBSERVED IN POSTERO-DORSAL VIEW

PREPARED BY H. R. DODGE
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
COMMUNICABLE DISEASE CENTER
ATLANTA, GEORGIA
OCT. 1951 REV. JULY 1953

*"POLLINOSE" REFERS TO A WHITISH DUSTING OF A SURFACE CAUSED BY MICROSCOPIC HAIRS

DHEW-ATLANTA, GA.

SUBORDER BRACHYCERA

FAMILY TABANIDAE
(horse flies, deer flies, mango flies)

General Characteristics

Members of the family TABANIDAE are sturdy flies with large hemispherical heads and very large eyes. The short antennae are characteristically extended horizontally and are composed of three segments, although the terminal segment is often annulated so distinctly as to give the appearance of six or seven segments. The proboscis is short, with broad, cutting blades. Only the females suck blood. The males feed on the nectar of flowers and on plant juices. The metamorphosis is complete.

Geographical Distribution

Horse flies, deer flies and mango flies are of world wide distribution.

Life Cycle and Habits

Typically, the eggs are deposited in masses on water plants or grass growing in marshy or wet ground. Within a week the eggs begin to hatch and the cylindrical larvae drop to the water, or make their way to damp earth, and live an aquatic carnivorous life, feeding on worms, snails, or insect larvae. Under optimum conditions, the larval stage lasts for several months or a year. The pupal period is of short duration, ranging from 1 to 3 weeks. The adults are usually quite large. They are strong fliers and persistent biters (Fig. 65).
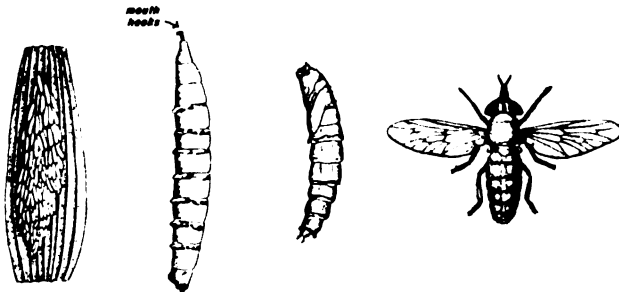
Figure 65
Life cycle of a tabanid fly:
Eggs, larva, pupa, and adult.

Relation to Man

The genus Chrysops is involved in the transmission of disease to man. The so-called mango fly, Chrysops dimidiata v.d. Wulp has been shown to be a vector of Loa loa (Cobbold) in various endemic regions of Africa, particularly in the Belgian Congo, and of tularemia in the United States. The horse and deer flies as a whole are well known pests of stock as well as of man. Several species of the genus Tabanus are known to transmit trypanosome infections to horses and cattle. Experimentally, anaplasmosis and anthrax can be transmitted by tabanids mechanically.

<div align="center">

SUBORDER NEMATOCERA

FAMILY PSYCHODIDAE
(moth flies, sand flies, owl flies)

</div>

General Characteristics

The members of this family are minute, dark colored insects whose bodies and wings are densely covered with hairs, thereby giving them the appearance of small moths, hence the name "moth flies." Scales may be found on various parts of the body, but never on the wings. The more or less spear-shaped wings, in addition to being densely covered with hairs, are characterized by the paucity of branching of the nearly parallel veins. The antennae have 12 to 16 segments and are usually fairly long.

The PSYCHODIDAE are generally divided into two sub-families, the blood-sucking and the non-blood-sucking. Only members of the blood-sucking genus Phlebotomus (also spelled Flebotomus) will be considered here.

Geographical Distribution

World wide in tropical and warm climates except in the East Indies and Australia.

Life Cycle and Habits

Immature Stages: The eggs of Phlebotomus, laid in batches of about 50, are deposited in dark, moist crevices of rocks or concrete walls, damp cracks in shaded soil, caves, embankments, or other places where there is an abundance of organic matter and sufficient moisture for their development. In 6 to 9 days the eggs hatch into caterpillarlike, mandibulate larvae which feed on any available organic debris. In the course of about 1 month, the larvae undergo three molts and transform into naked pupae. The pupal stage lasts about 10 days. Under favorable conditions, a complete cycle from egg to adult requires about 6 to 8 weeks (Fig. 67).
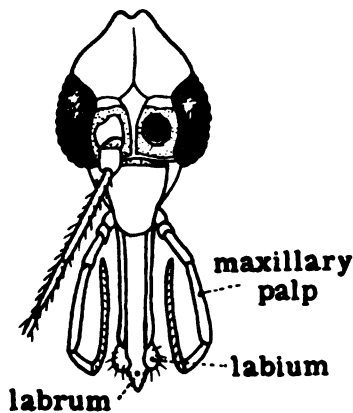

maxillary
palp

labium

labrum

<div align="center">

Figure 66
Head and mouth parts
of Phlebotomus

</div>

Adult Stage: Sand flies of the genus Phlebotomus are small, hairy midgés, 2 to 3 mm. long, easily recognized by the position of the wings which are elevated and spread to form a "V." They readily penetrate ordinary screens or nets and are almost entirely nocturnal. Only the females suck blood.(Fig. 66). At night, sand flies may be found both indoors and out, feeding on man or animals or resting on walls near by. During the day they seek a variety of shelters. They may be found in the darker corners and near the ceiling of sleeping quarters. The most common outdoor shelters are masonry cracks, stone walls, excavations, animal burrows, hollow trees, and deep cracks in soil. Sand flies are easily seen on light-colored walls; however, tobacco

<div align="center">

135

</div>

smoke is helpful in searching for them on rough, dark surfaces or in recesses, because it causes them to move and thus reveal themselves.

The breeding places are difficult to demonstrate but are characteristically located in loose soil or organic debris beneath stones or in masonry cracks -- in much the same kinds of places as the outdoor shelters of the adults. In open country free of stones, they may breed in animal burrows or in open soil. The flight range is believed not to exceed 100 to 200 yards where breeding places are near human habitations. However, in open country with breeding places associated with widely scattered rodent burrows, flight ranges of 1,500 yards have been measured.

Those species whose habits have been studied tend to progress by means of short flights, alighting on stones, plants, or other objects as they approach a house. Instead of entering at once, sand flies tend to alight on the outer walls, and then in a series of short, hopping flights with relatively long pauses make their way into the building. Once inside, they may rest on the walls for some time before attempting to feed. A similar lack of haste has been observed as sand flies emerge from stone walls during the first hours of darkness. They may rest at the openings of such shelters for as much as half an hour before taking flight. These flight habits render sand flies vulnerable to the residual action of DDT. The surfaces on which they must alight and on which they spend considerable time are easily accessible and can be transformed into lethal traps or barriers.
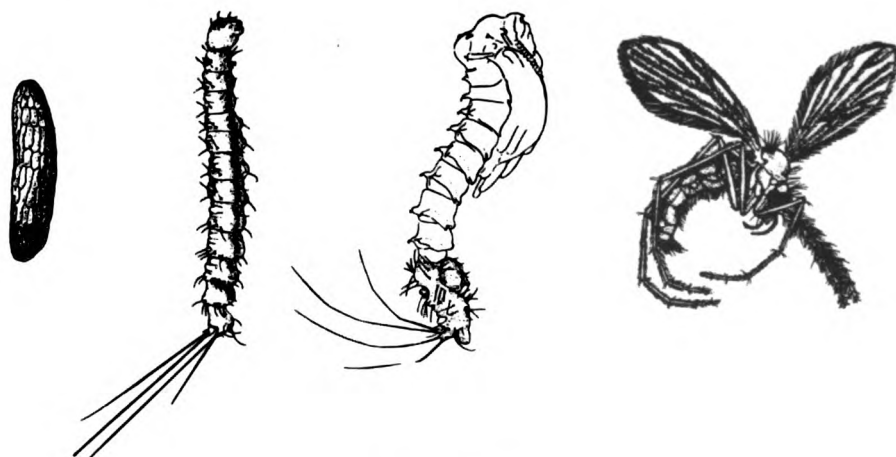
Figure 67
Life cycle of Phlebotomus: Egg, larva, pupa, and adult

Relation to Man

The principal diseases transmitted by members of the genus Phlebotomus are: Pappataci fever (sand fly fever), leishmaniases (kala-azar and oriental sore), and verruga peruana (Oroya fever). In addition to the role these sand flies play in the transmission of disease, they are vicious biters. The bite of a sand fly causes a lesion which is inflamed, hardened, with a wheal formation, followed by pruritis, nausea and occasionally fever.

136

FAMILY HELEIDAE
(biting midges, punkies, sand flies)

General Characteristics

The members of the family HELEIDAE are very small, slender, blood-sucking gnats, seldom exceeding 2 to 3 mm. in length. They are easily distinguished by the peculiar venation of the wings; the first two veins are very heavy, while the others are somewhat indistinct (Fig. 70). The wings are more or less covered with erect setae or hairs and, in many species, are marked with pale spots on a dark background. The antennae have 15 segments and the palpi usually 5.

Geographical Distribution

Widely distributed in the tropical and temperate regions.

Life Cycle and Habits

The eggs are laid in a variety of places but mainly in water-saturated sand or soil. The larvae are small, legless, wormlike creatures, with a small brown head and 12 body segments. The slender brown pupae are provided with two short breathing tubes on the thorax. They float nearly motionless in a vertical position, the respiratory tubes in contact with the surface film. The entire life cycle requires from 6 to 12 months. In the Pacific, large numbers of larvae and pupae have been found in the numerous coral pockets above high tide levels (Fig. 69).
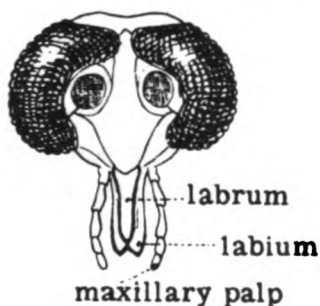
Locally these midges occur in sufficient numbers to make them almost intolerable. They bite chiefly in the evening and very early in the morning. In some species the bite is very painful and extremely irritating, causing nodular, inflamed swellings that itch persistently for several days or even weeks (Fig. 68). The insects prefer to bite at some point where their progress is impeded, such as around the hat band, at the belt line, or at the shoe tops.
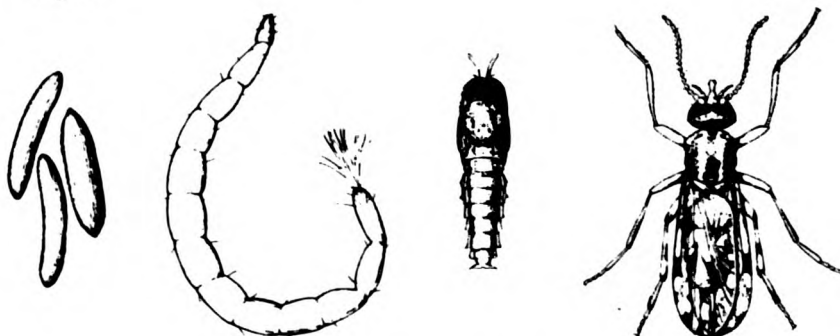

----labrum

----labium

maxillary palp

Figure 68
Head and mouth parts
of Culicoids

Figure 69
Life cycle of Culicoides: Egg, larva, pupa, and adult
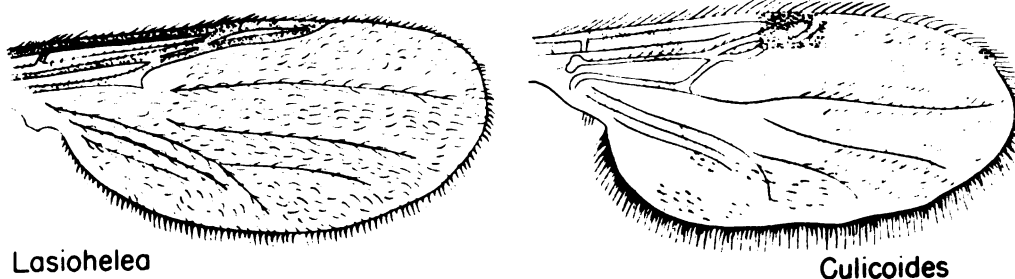
137

Lasiohelea   Culicoides

Figure 70.
Wings of two blood-sucking genera of the family HELEIDAE

Relation to Man

The great majority of the species which attack man belong to the genus Culicoides. These blood-sucking midges have been accused of transmitting South American dermal leishmaniasis and have been proved to serve as the intermediate hosts of two filarial worms considered to be nonpathogenic to man, Acanthocheilonema perstans in Africa, British Guiana and New Guinea, and Mansonella ozzardi in the British West Indies.

FAMILY SIMULIIDAE
(black flies, buffalo gnats)

General Characteristics

The SIMULIIDAE are small (1 to 5 mm. long), dark, chunky flies with biting-sucking mouth parts (Fig. 71). Distinguishing characteristics are the hump-backed appearance and the relatively short, broad, clear wings in which only the anterior veins are well developed. The antennae are many jointed (10 to 11) but are short with beadlike segments instead of being long and filamentous as in other members of the NEMATOCERA.
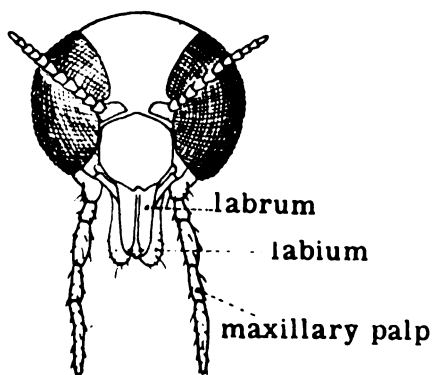
Geographical Distribution

Cosmopolitan

Life Cycle and Habits (Fig. 72)

labrum
labium
maxillary palp

Figure 71
Head and mouth parts
of Simulium

Immature Stages: The small, glistening yellow eggs are laid in masses of about 500 on stones and vegetation in swiftly running streams. They hatch in 5 to 30 days and the larvae attach themselves to rocks or sticks in the water. After about a month the larvae spin cocoons and pupate, fastened to the rocks. The entire life cycle usually requires from

138

10 to 13 weeks, but <u>Simulium</u> may overwinter either in the egg or larval stage.

   <u>Adult Stage</u>: Black flies usually appear in large numbers. They make little noise in flight and alight on the skin and bite quickly. They are active mainly during the daylight hours and seldom enter houses. The adults are short-lived.
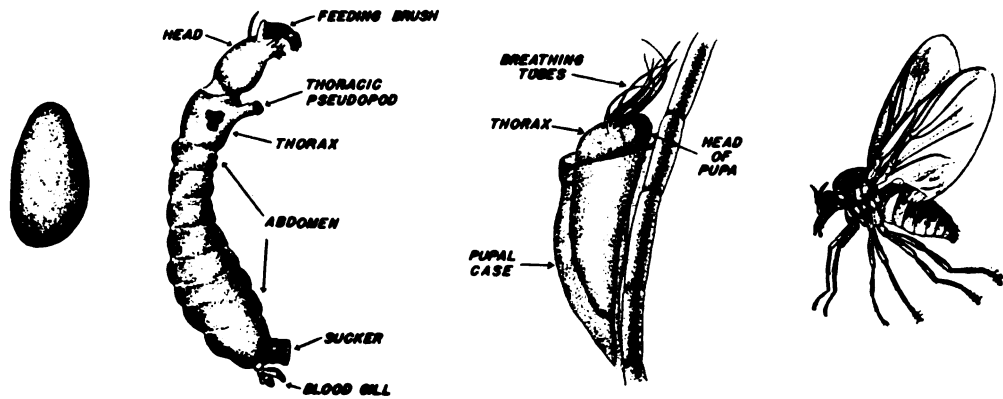

<u>Figure 72.</u>
Life cycle of <u>Simulium</u>: Egg, larva, pupa, and adult

Relation to Man

   Only one genus of this family has been found to transmit disease. Species of <u>Simulium</u> are intermediate hosts for the filarial worm, <u>Onchocerca</u> <u>volvulus</u> (Leuckart), the organism causing onchocerciasis in certain parts of Africa, Mexico, and Central America. This organism has also been found to transmit tularemia. Black flies are vicious and persistent biters causing swelling and pruritis. They attack both human beings and domestic animals, sometimes killing livestock. As in mosquitoes, only the females are able to pierce the skin.

PLATE XXIV.
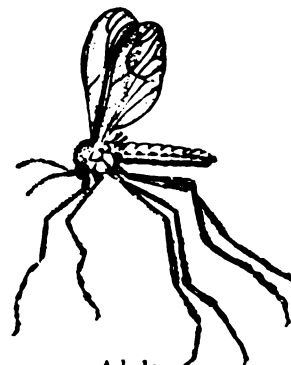
LIFE CYCLES OF SOME NON-BITING MOSQUITO-LIKE FAMILIES
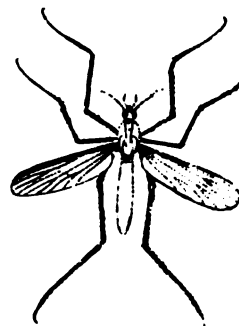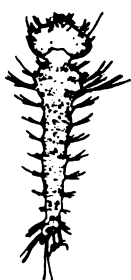
Larva   Pupa   Adult

Family Dixidae: Dixa

Larva   Pupa   Adult

Family Chaoboridae: Chaoborus

Corethrelia   Eucorethra   Mochionyx

Other Chaoborid Larvae

140

FAMILY CULICIDAE
(mosquitoes)

General Characteristics

All mosquitoes are included in the family CULICIDAE, a group of nematocerous flies in which the wings are scaly; the third vein is simple, while the second and fourth are branched; and the proboscis is long. They in turn, are divided into two general groups, the anophelines (including the genus Anopheles) and the culicines) (almost all the rest of the mosquitoes). Two other groups of delicate mosquito-like gnats resemble the true mosquitoes but do not have a long proboscis and cannot suck blood, nor do they have scales on the veins of their wings. The larvae, too, are oftentimes difficult for beginners to differentiate. Many of these nonbiting gnats are included in the two families DIXIDAE and CHAOBORIDAE and are shown in Plate XXIV.

Relation to Man

Of all the insects that jeopardize the health of man, mosquitoes rank first. Not only do they transmit disease, but they occur in such numbers that they cause great annoyance. Three genera are of particular medical concern, Anopheles, Aedes, and Culex. Human malaria is transmitted only by mosquitoes of the genus Anopheles, and dengue only by the genus Aedes. Yellow fever is transmitted from man to man by the common yellow fever mosquito, Aedes aegypti (Linn.). It also occurs as an infection of certain animals of tropical forests, transmitted from animal to animal and incidentally to man by various species of mosquitoes and, possibly, by other anthropods.

Several genera, including Culex, transmit certain species of filarial worms that produce the disease referred to as filariasis. In addition, human encephalitides, caused by various viruses (equine, Japanese, St. Louis) are transmitted by mosquitoes. A South American bot fly, Dermatobia, often captures and lays its eggs on mosquitoes for transportation to the skin of man or animals, where they hatch and the resulting larvae cause myiasis.

Pest mosquitoes affect the comfort and efficiency of man through severe annoyance, itching bites, loss of sleep, and nervousness. They have caused death or loss of weight in domestic animals, and reduced egg and milk production. Psorophora confinnis (L. -A) in two days caused the death of 80 cattle and 67 swine in Florida.

141

External Anatomy

The adult mosquito possesses one pair of wings and a pair of halteres, charac-
teristics which place it in the Order Diptera (Plate XIII). They are very fragile in-
sects with long slender bodies ranging from a little over 1/16 inch to about 1/2 inch in
length. The head is more or less rounded with large compound eyes. Its antennal
characters (long and many segmented) assign it to the Suborder NEMATOCERA. They
are placed between the eyes on the front of the head. In the male they are characteris-
tically bushy, whereas in the female they are sparsely haired (Fig. 75).   It falls into
the family CULICIDAE by virtue of wing venation (the third vein being unbranched
between two branched veins – the second and fourth), the scales on the veins of the
wings, and the long proboscis (Fig. 77).

In generic identification the following structures should be particularly noted; the
shape of the scutellum, which is just posterior to the mesonotum; the presence or ab-
sence of spotting of the wings caused by aggregations of dark and light scales; the
length of the maxillary palps in relation to the length of the proboscis, the shape of the
tip of the abdomen, and the presence or absence of postspiracular bristles on the side
of the thorax just behind the anterior spiracle (Fig. 73).

Mouth parts: The elongate gutter-shaped labium encloses the six needlelike sty-
lets of the mouth parts, the entire structure being termed the proboscis. The stylets
include the labrum epipharynx, the hypopharynx, 2 maxillae and 2 mandibles. The
labium acts only as a protective sheath and remains on the surface when the mosquito
bites. The labrum is horseshoe-shaped with its open side sealed by the close applica-
tion of the delicate mandibles and hypopharynx. The closed tube thus formed functions
as a food channel. The hypopharynx is pierced on its underside for its entire length by
the minute salivary duct. Below these tube-forming structures are the principal skin
cutting stylets, the toothed maxillae (Fig. 76, B & C). When the female mosquito
feeds, she works the entire ensemble of stylets into the skin. The liplike, apical,
paired lobes of the labium (labella) continue to grasp the stylets at the skin surface as
they slide in. At the same time, the labium elbows back, leaving the stylets exposed
between the head and the labella (Figure 76 A). Only the female mosquitoes feed on
blood. In the males, with mandibles and maxillae very much reduced or lacking, feed-
ing is confined to plant juices or other available sweets.

The maxillary palpi are about as long as the proboscis in the anophelines. In the
male they are enlarged at the tip, while in the female there is no enlargement. In the
culicines the female palpi are quite short, but in the male they are densely haired,
long and elbowed (Fig. 75).

Wings and Wing Spots: The veins in the wings are characteristically arranged in
each group of insects. Thus in the CULICIDAE the third vein is unbranched and loca-
ted between two branched veins, the second and fourth. In addition, minor variations
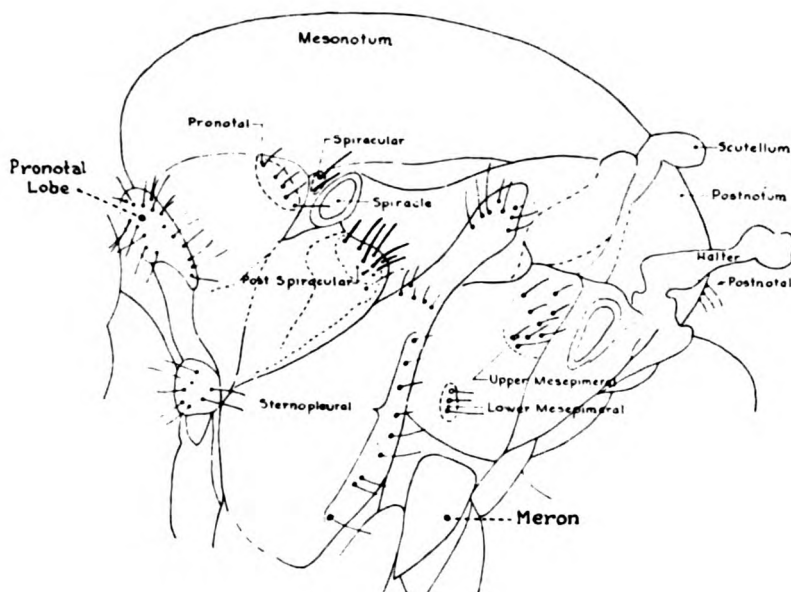
142

Figure 73.
Side view of mosquito thorax, showing location
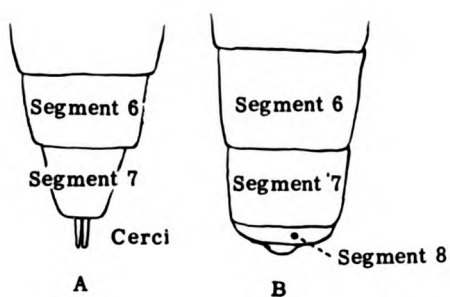**of important diagnostic bristles**

Figure 74.
Characteristic shapes of tip
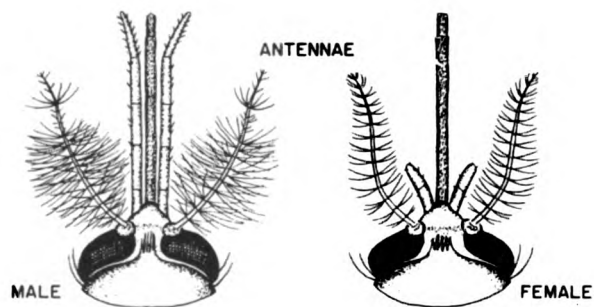of female abdomen.
A. Aedes. B. Culex.

Figure 75.
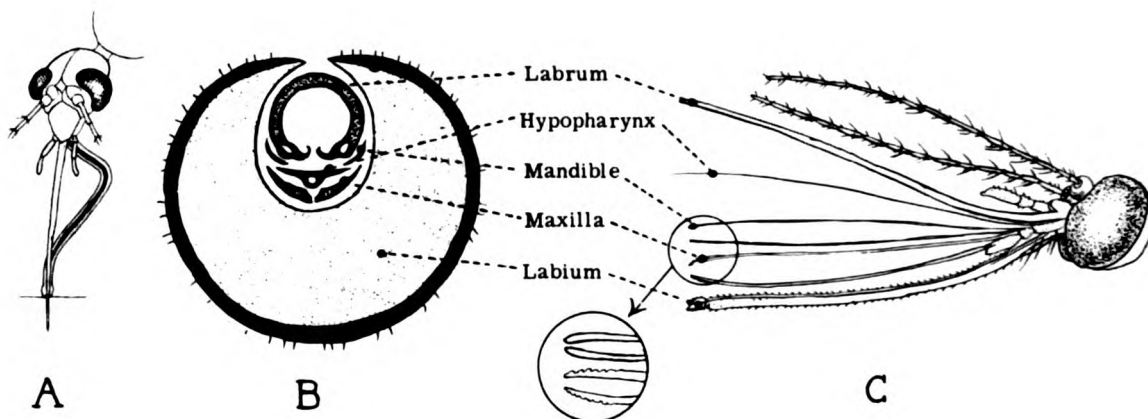Sex differentiation of the adult
mosquito.

143

Figure 76.
Mosquito mouth parts. A. Female mosquito feeding.
B. Cross section of proboscis. C. Stylets dissected
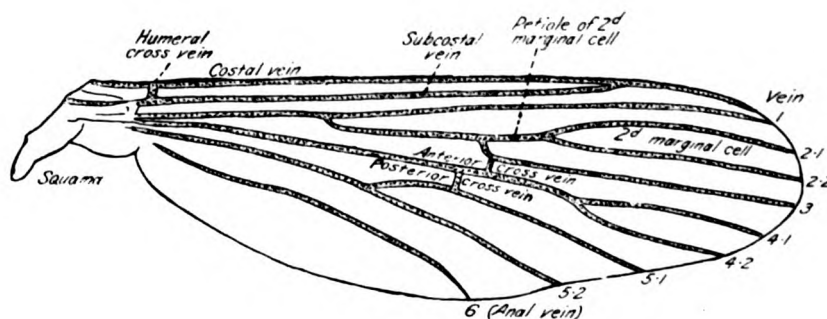out of labial gutter.

Figure 77.
Denuded wing of mosquito, with veins labeled. The corresponding symbols
for the veins in the Comstock-Needham system are: 1, R_1; 2.1 and 2.2,
R_2 and R_3; 3, $R_{4/5}$; 4.1, $M_{1/2}$; 4.2, M_3; 5.1 and 5.2, Cu_1 and Cu_2, anter-
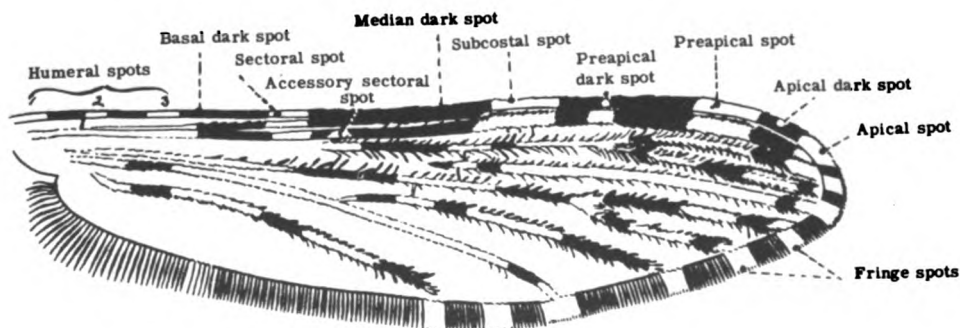ior cross vein, r-m; posterior (basal) cross vein, m-cu.

Figure 78.
Anopheline wing with marginal spots designated.

144

in the vein pattern and variations in the grouping, shape, and color of the wing scales are used in dividing the mosquitoes themselves into groups.

A few anophelines have unspotted wings; the wings of the great majority, however, show definite dark and light areas which are due to aggregations of dark and light scales. The wing patterns thus produced are characteristic of species and are described in the keys according to the systems illustrated in Figures 77 and 78. It must be remembered that a few culicines have prominently marked wings and have frequently been mistaken for anophelines. Careful examination of structures other than the wings will readily identify these spotted-wing forms as mosquitoes other than anophelines. Behind the wings is a pair of halteres which serve in maintaining equilibrium.

<u>Abdomen</u>: The abdomen is made up of ten segments, but only eight are readily discernible since the last two are modified into sexual organs. The abdominal scales of the culicines are often utilized in identification.

The terminal segments of the male abdomen are modified to form organs which function in clasping and impregnating the female. Oftentimes these terminalia exhibit characteristic structures which are helpful in differentiating species. In order to study these structures satisfactorily, it is necessary to clip off the last few segments of the abdomen, soften and clear them in potassium hydroxide, and mount them on a microscopic slide. After clipping off the tip of the abdomen, place it in 90 per cent alcohol for 15 or 20 minutes. Transfer it to 10 or 20 per cent potassium hydroxide for 20 or more minutes, rinse in water, and add a few drops of glacial acetic acid to neutralize the potassium hydroxide. Dehydrate the specimen by blotting and mount in chloral-gum media, or clear by adding a drop of clove oil, wash in xylol after the blotting, and mount in balsam. It is best to use crushed glass under the coverslip to avoid crushing the specimen.

Among the diagnostic characters of the male genitalia is the elongated, sclerotized phallosome, which is usually surmounted by one or more pairs of small <u>leaflets</u>. The latter frequently vary in number and shape in different species. Below the phallosome, and connecting the bases of the <u>side pieces</u>, is a membrane expanded on each side into a lobe having several spinelike hairs on the posterior margin. The lobes are called the <u>claspettes</u>, and the shape or arrangement of their spines is important in the classification of species. The modified hairs on the basistyle (side piece) also show differences of subgeneric value (Fig. 79).
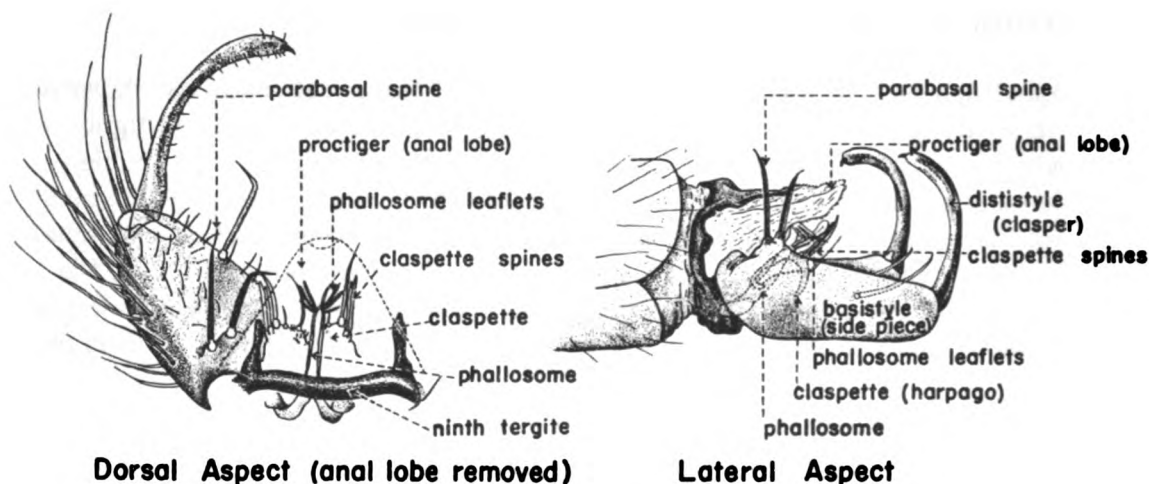
145

parabasal spine
proctiger (anal lobe)
phallosome leaflets
claspette spines
claspette
phallosome
ninth tergite

Dorsal Aspect (anal lobe removed)

parabasal spine
proctiger (anal lobe)
dististyle (clasper)
claspette spines
basistyle (side piece)
phallosome leaflets
claspette (harpago)
phallosome

Lateral Aspect

Figure 79.
Male terminalia of an anopheline mosquito

Internal Anatomy

The adult mosquito, being an insect, has a dorsal heart and a ventral nervous system. Between the alimentary tract and the body wall is the space filled with blood, or the hemocoel.

The tracheal system opens with paired spiracles on each of the last two thoracic segments, and the first eight abdominal segments.

The salivary glands are paired, and located ventrally in the anterior part of the thorax. The ducts leading from the glands, join in a common salivary duct which connects with a salivary pump before emptying into the pharynx.

The buccal cavity at the base of the proboscis opens by means of a valve into the pharynx. The esophagus is short and has two dorsal and one ventral diverticula called food resevoirs. It is opened posteriorly by the esophageal valve. The pharynx and esophagus form the fore intestine which is an invagination of the body wall and is consequently lined with chitin. The mid-gut is non-chitinized extending from the middle of the thorax well into the abdomen where it joins the larger stomach. The chitinized hind gut extends through a few of the terminal abdominal segments and consists of a slender ileum and colon, with an enlarged rectum connected to the anus. The five excretory Malpighian tubules open into the digestive tract at the posterior extremity of the mid-gut (Fig. 80).

The reproductive system of the female consists of a pair of ovaries attached in the fourth segment of the abdomen emptying into oviducts which terminate in the vagina on the ninth segment. One to three spermathecae are present, depending on the species.

146

Similarly, the genital system of the male consists of a pair of testes opening into the vasa deferentia, with seminal vesicles, which are joined by a common ejaculatory duct. Accessory glands are present.
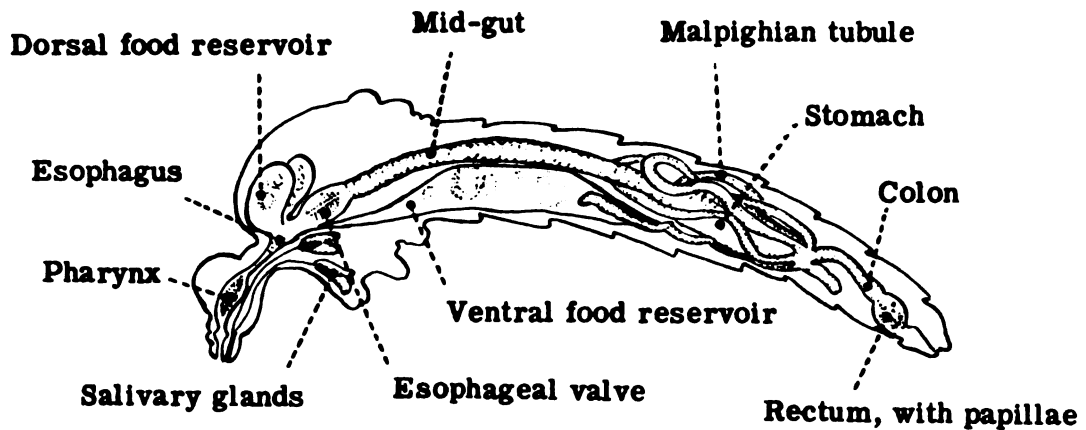

Figure 80.
Alimentary canal of a mosquito

Life Cycle

The eggs of some mosquitoes are laid individually on ground that is subject to flooding, while others deposit them either separately or in rafts on the surface of water.

Psorophora and some of the Aedes lay their eggs on the ground, waiting sometimes for months for flooding to cause them to hatch. Many species are able to survive in this stage for one or two years without water.

Certain species such as Aedes triseriatus (Say) and A. aegypti as well as members of the genus Orthopodomyia lay their eggs above the water level in tree holes or in containers, depending upon rain to raise the level and immerse them.

The eggs that are placed in rafts may be in groups of 100 or more, the rafts floating a few days until the eggs hatch. Culex, Culiseta, Mansonia, and Uranotaenia are examples of mosquitoes that deposit their eggs in this manner.

Anophelines lay their eggs individually on the surface of the water. They are more or less pointed at one end, boat-shaped, and are provided with "floats." The female deposits batches of 100 to 300 eggs which often arrange themselves in mesh-like, geometric patterns due to the effects of surface tension. The incubation period is normally two or three days. Another genus, Toxorhynchites, deposits eggs individually on the surface of water, but they are not furnished with floats, the eggs being kept afloat by bubbles of air confined among the spines on the shells.

147

Larva: When mosquito eggs hatch, tiny larvae, or "wiggle-tails" just visible to the naked eye emerge. As indicated above, some live in artificial containers, in tree holes, in plants that hold water, in pools, marshes and in temporary waters caused by flooding. Mosquito larvae are air breathers, either obtaining it at the surface of the water, or from the vascular roots of certain aquatic plants.

As they feed and grow larger, they pass through four instars requiring about 4 to 10 days, shedding their outer skins between each instar. The mouth parts consist of a series of brushes on the underside of the head together with grinding and holding structures, enabling the larva to obtain small aquatic organisms and other material.

Anopheline larvae are readily recognized in life by the fact that they have no elongate air tube and lie just under and parallel to the water surface, whereas in culicine larvae the air tube is well developed and the body hangs downward at an angle of 45 degrees, touching the surface film only with the tip of the air tube (Fig. 81).

ANOPHELINE   CULICINE
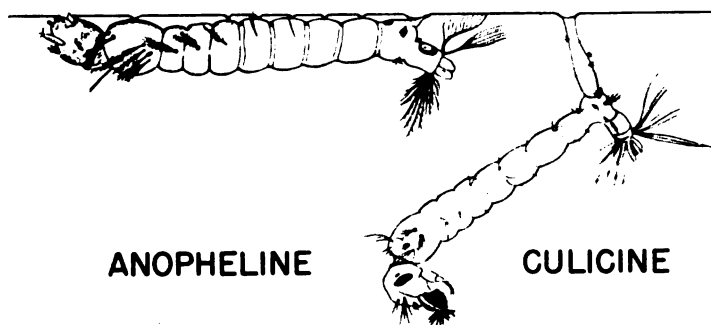
Figure 81.
Positions assumed by larvae of anophelines and
culcines at the surface of the water

Pupa: When its growth is completed, the fourth-instar mosquito larva molts and transforms into a pupa or "tumbler." The pupa moves actively in the water but does not feed. The enlarged anterior part includes the head and thorax in a single sclerotized capsule. Two breathing trumpets project from this cephalothorax. The last segment of the abdomen bears a pair of paddles which enable the pupa to "tumble" about (Fig. 82).

148

Figure 82.
Pupa of mosquito at surface of water

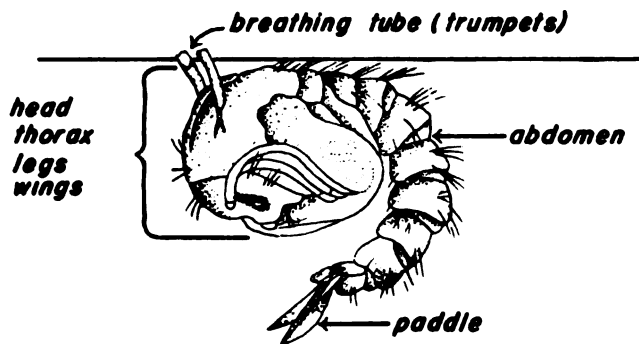Within the pupa a marked transformation is taking place; new structures are forming which will adapt the insect to terrestrial life. Eventually the adult within emerges through a slit on the back of the thorax, spreads and dries its wings while clinging to the old pupal case on the surface of the water, and flies away.

Biology

The various species of mosquitoes differ greatly as to rate of development, feeding habits, resting sites of adults, mode of hibernation, choice of breeding grounds, and other characteristics and habits. This "species individuality" has great importance in disease control, since a knowledge of it often enables the entomologist to concentrate control procedures against the particular, important species concerned ("species control"). It also eliminates the necessity for the often far more expensive control measures directed against all kinds of mosquitoes in general.

Feeding Habits

Some kinds of mosquitoes do not suck blood; others restrict themselves to non-mammalian blood, attacking birds, reptiles, amphibia, and other hosts. Males do not suck blood; their maxillae and mandibles are so reduced that they are unable to pierce the skin. They supposedly feed on the nectar and juices of plants, as do the females of some species.

Light, air movement, temperature, and humidity, as well as the attractiveness of the host animal and the time since the last feeding influence the biting of mosquitoes.

When a mosquito bites, she first injects a small amount of saliva into her victim. This saliva is generally considered to function as an anticoagulant, but experiments indicate that, with a few species at least, it has no such effect. It is further generally assumed that the irritating effect of mosquito bites is a direct result of the injection of

149

the saliva itself. Careful experiments, again on only a very few species, however, suggest that the irritation (swelling, reddening, and itching) may be due mainly to the regurgitation, into the feeding puncture, of yeasts and enzymes from the alimentary canal of the mosquito.

Flight Habits

From the standpoint of control, the flight habits of mosquitoes are of much importance. These vary so greatly from species to species and sometimes with locality that significant generalizations are difficult to make.

The distance that mosquitoes will fly from their breeding places probably varies not only with the species but with the density of adults in the area, the nearness of suitable hosts, and the air currents.

Hibernation

Some mosquitoes in temperate climates overwinter in the egg stage and hatching begins with the first warm days in spring. In some species the fertilized females hibernate in caves, barns, and similar places. A very few species overwinter as larvae. One of these, Wyeomyia smithii (Coq.), passes part of its larval stage embedded in ice.

It is difficult to generalize concerning the seasonal development of mosquitoes in tropical regions. In certain areas, conditions suitable for development are present throughout the year and there is no discontinuity of generations. In other areas, the dry season may be long enough to interrupt the appearance of new generations.

Longevity of Adults

The determination of the length of life of adult mosquitoes under natural conditions is difficult. Obviously, in those species that hibernate as adults, the fecundated females must survive for several months from one breeding season to the next.

Longevity is unquestionably reduced at very high temperatures and very low humidities, conditions which thus have great influence on the transmission of such diseases as malaria. Obviously, if the female mosquitoes cannot live long enough to mature their parasites, they cannot transmit the disease. This condition has actually been shown to prevail in some areas at certain seasons of high temperatures and low humidity.

Egg-Laying Habits

The egg-laying habits of mosquitoes vary widely. The factors that influence the female mosquitoes in their selection of sites for egg-laying are not well understood. They may be chemical or physical or both and probably vary greatly from species to species and from area to area.

Larval Habits and Habitats

All mosquitoes live out their larval lives in water, but the typical breeding places of the different species vary greatly in their characteristics.

It is obvious that control measures must vary greatly, and effective mosquito control in any locality must be based on intimate knowledge of the life habits of the species involved. Control measures for one area may not be effective in another, and adaptations must constantly be made to fit the difference in biology of the species.

In connection with disease control measures, it must be borne in mind that complete elimination of the adults is unnecessary, for below a certain minimum density, mosquito-borne diseases will disappear of their own accord. This minimum number of mosquitoes necessary to perpetuate disease depends upon many factors, and no formula is available from which this number can be readily determined. However, since even very careful field control measures rarely result in complete elimination of mosquitoes, it is still important to strive for as complete elimination as possible and to use every means available to attain this end.

Key to the Three Genera of Mosquitoes of Greatest Medical Importance

Eggs:

1. Eggs laid singly 2

   Eggs laid in groups called "rafts;" individual eggs without floats ......Culex

2. Eggs with floats .... Anopheles

   Eggs without floats .... Aedes
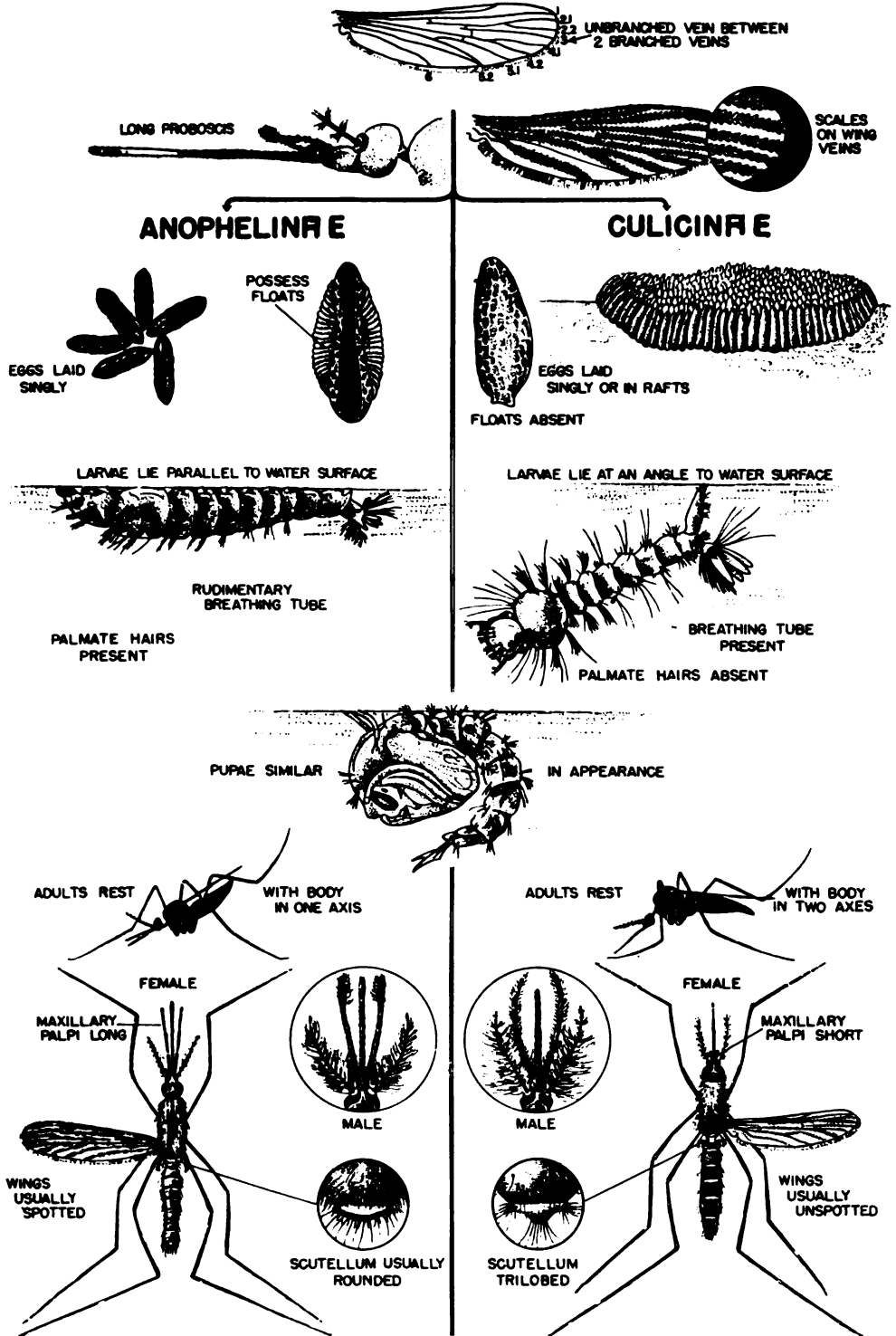
Larvae:

1. Larvae rest parallel to surface of water; breathing tube rudimen-
   tary; a series of palmate or float hairs on the abdomen .... Anopheles

   Larvae rest at an angle to the surface of water; well-developed
   breathing tube; without palmate or float hairs on the abdomen 2

2. With a single tuft of hairs beyond each row of pecten teeth on
   breathing tube .... Aedes

   With more than one hair tuft beyond each row of pecten teeth on
   breathing tube .... Culex

Adults:

1. Scutellum evenly rounded; wings usually spotted; maxillary palps
   of female as long or nearly as long as proboscis; resting position
   with proboscis and body in one axis .... Anopheles

   Scutellum trilobed; wings not spotted; maxillary palps of female
   much shorter than proboscis; resting position with proboscis
   and body in two axes 2

2. Postspiracular bristles present; tip of abdomen of female usually
   pointed; cerci protruding; thorax often with silver or white
   markings .... Aedes

   Postspiracular bristles absent; tip of abdomen of female usually
   blunt; cerci retracted; thorax usually dull colored .... Culex

PLATE XXV.

FAMILY : CULICIDAE

2 UNBRANCHED VEIN BETWEEN
2 BRANCHED VEINS

LONG PROBOSCIS

SCALES
ON WING
VEINS

ANOPHELINAE

CULICINAE

POSSESS
FLOATS

EGGS LAID
SINGLY

EGGS LAID
SINGLY OR IN RAFTS

FLOATS ABSENT

LARVAE LIE PARALLEL TO WATER SURFACE

LARVAE LIE AT AN ANGLE TO WATER SURFACE

RUDIMENTARY
BREATHING TUBE

BREATHING TUBE
PRESENT

PALMATE HAIRS
PRESENT

PALMATE HAIRS ABSENT

PUPAE SIMILAR

IN APPEARANCE

ADULTS REST

WITH BODY
IN ONE AXIS

ADULTS REST

WITH BODY
IN TWO AXES

FEMALE

FEMALE

MAXILLARY
PALPI LONG

MAXILLARY
PALPI SHORT

MALE

MALE

WINGS
USUALLY
SPOTTED

WINGS
USUALLY
UNSPOTTED

SCUTELLUM USUALLY
ROUNDED

SCUTELLUM
TRILOBED

153

KEY TO COMMON GENERA AND SPECIES OF ADULT
FEMALE MOSQUITOES OF THE U.S.*

1. Palpi about the same length as proboscis (Fig. 83) ... <u>Anopheles</u> 7

   Palpi much shorter than proboscis (Fig. 85) 2

2. Thorax or wings with conspicuous lines of shiny bluish or
   purplish scales; very small species .... <u>Uranotaenia</u> 53

   Thorax and wings without lines of bluish or purplish scales;
   medium to large species 3

3. With the three following characters in combination wing scales
   very broad, mixed dark and light colored (Fig. 89); tip of abdomen
   blunt (Fig. 88); and proboscis pale-banded (Fig. 111) .. <u>Mansonia</u> 52

   Without all three of the above characters in combination 4

4. Tip of abdomen pointed; segment 7 of abdomen narrowed, segment 8
   much narrowed and retractile (Fig. 87); postspiracular bristles
   present (Fig. 73) 5

   Tip of abdomen blunt; segment 7 of abdomen not narrowed, segment 8
   short but not retractile (Fig. 88); postspiracular bristles absent (Fig. 73)..... 6

5. Spiracular bristles absent (Fig. 73); abdomen with pale scaling usually
   at the bases of segment 1 to 5 (Figs. 109, 110, 115,-118) ....<u>Aedes</u> 15

   Spiracular bristles present (Fig. 73); abdomen with pale scaling usually
   at the apex of segments 1 to 5 (Fig. 127) ....<u>Psorophora</u> 37

6. Spiracular bristles absent (Fig. 73); base of subcostal vein without a
   tuft of hairs on underside of wing .... <u>Culex</u> 43

   Spiracular bristles present; base of subcostal vein with a tuft of hairs
   on underside of wing .... <u>Culiseta</u> 49

GENUS <u>ANOPHELES</u>

7. Wing veins with distinct spots or areas of white or yellowish-white
   scales (Fig. 93) 8

   Wing veins entirely dark scaled (Fig. 94) 11

*After Ralph C. Barnes and Harry D. Pratt, U.S. Public Health Service, Dept. of
H.E.& W., CDC, Atlanta, Georgia

154

8. Palpi marked with white rings or bands (Figs. 95, 101, 102) 9

Palpi entirely dark (Fig. 97) .... <u>Anopheles</u> <u>punctipennis</u>

9. Wings with two spots of white scales on front margin, one at outer
third and a smaller one at tip (Fig. 99) 10

Wings with only one spot of white scales on front margin, located
near tip (Fig. 100)......... <u>Anopheles</u> <u>crucians</u>, <u>A</u>. <u>bradleyi</u>, and <u>A</u>. <u>georgianus</u>

10. Last segment of palpi entirely white. Occurs in South Central
United States (Fig. 101) .... <u>Anopheles</u> <u>pseudopunctipennis</u>

Last segment of palpi tipped with black. Occurs in Southwestern
United States (Fig. 102) .... <u>Anopheles</u> <u>franciscanus</u>

11. Palpi with distinct but narrow white rings; halter knobs pale
(Figs. 95, 96) .... <u>Anopheles</u> <u>walkeri</u>

Palpi entirely dark; halter knobs dark (Figs. 97, 98) 12

12. Wings with four dark spots; (Fig. 104) light knee spots present
(Fig. 92) 13

Wings not distinctly spotted; knee spots absent, occurs only on
Atlantic and Gulf Coasts .... <u>Anopheles</u> <u>atropos</u>

13. Wing fringe with a patch of coppery or golden scales at the apex
(Fig. 103) .... <u>Anopheles</u> <u>occidentalis</u> and <u>A</u>. <u>earlei</u>

Apex of wing uniformly dark (Fig. 104) 14

14. Occurs east of the Rocky Mountains .... <u>Anopheles</u> <u>quadrimaculatus</u>

Occurs in the Rocky Mountain area and Westward.......... <u>Anopheles</u> <u>freeborni</u>

GENUS <u>AEDES</u>

15. Tarsal segments ringed with white (Figs. 105, 107, 108) 16

Tarsal segments not ringed with white (Fig. 106) ...., 29

16. Tarsi with white rings at both ends of some of the segments (Fig. 105) 17

Tarsi with white rings only at the bases of segments (Figs. 107, 108, 113A).... 20

155

17. Upper surface of abdomen with a mid longitudinal stripe of white scales
or almost entirely white scaled; (Fig. 109) wing scales mixed brown
and white, the white scales predominating .... Aedes dorsalis

Upper surface of abdomen mostly dark scaled; patches of white scales
sometimes present at the middle or toward the sides; wing scales
almost all dark (Fig. 110) 18

18. Front of wing with a patch of white scales near base 19

Wing scales entirely dark. Occurs throughout most of the
United States .... Aedes canadensis

19. Pacific coast species; mesonotum dark brown with a broad-median
patch of goldn brown scales more or less enclosed by a curving band
of white or yellowish-white scales, sides scaled; tree hole
species .... Aedes varipalpus

Eastern species; mesonotum dark brown, almost black, with a broad
median stripe of reddish-brown scales, the sides and scutellar area
with lemon-yellow or golden to whitish scales; rock pool
species .... Aedes atropalpus

20. Proboscis ringed with white (Fig. 111) 21

Proboscis not ringed with white (Fig. 112) 24

21. Upper surface of abdomen with a longitudinal stripe of white or
yellowish scales (Fig. 115) 22

Upper surface of abdomen dark with basal cross bands of white
scales on each segment (Fig. 116). A salt marsh species occur-
ring along the Atlantic, Gulf, and Pacific Coasts .... Aedes taeniorhynchus

22. Wing scales entirely dark; first segment of hind tarsus without a
pale ring at middle (Fig. 107) .... Aedes mitchellae

Wing scales mixed dark brown and white 23

23. Abdominal stripe yellowish; first segment of hind tarsus with a
definite yellowish ring at middle; last segment of hind tarsus
entirely white. Common along Atlantic and Gulf Coasts ....,Aedes sollicitans

Abdominal stripe white; first segment of hind tarsus with median
ring white, or lacking; last segment of hind tarsus largely dark.
A western species associated with irrigated areas.. (in part) Aedes nigromaculis

156

24. Upper surface of abdomen with a longitudinal stripe of white
scales .... (in part) Aedes nigromaculis

Upper surface of abdomen without a longitudinal stripe of white scales....... 25

25. Mesonotum with four conspicuous lines of silvery-white scales,
the two inner ones straight, the outer ones curved.
(Fig. 114). Occurs only in the South .... Aedes aegypti

Mesonotum without distinct lines of white scales 26

26. Wing scales mixed dark and white; basal white rings of hind tarsi broad,
usually several times wider than diameter of segment (Fig. 108) 27

Wing scales entirely dark; (Fig. 90) basal white rings of tarsi narrow,
usually little wider than diameter of tarsal segment (Fig. 118) 28

27. Wing scales unusually short and broad (Fig. 89). A salt-marsh breeder
occurring only along the California Coast .... Aedes squamiger

Wing scales long and narrow (Fig. 90). Fresh water species occurring
throughout Northern United States .... Aedes stimulans group*

28. Pale bands on upper surface of abdomen with a v-shaped notch at back,
seventh segment largely dark scaled (Fig. 117) .... Aedes vexans

Abdominal pale bands without a v-shaped notch; seventh segment almost
entirely pale scaled. Occurs only along upper Atlantic Coast .... Aedes cantator

29. Wing scales mixed black and white 30

Wing scales uniformly dark 31

30. Upper surface of abdomen with a median longitudinal stripe of white
scales, or almost entirely pale scaled .... Aedes spencerii

Upper surface of abdomen black with segmental cross bands of
white scales .... Aedes idahoensis

31. Mesonotum with one or two conspicuous stripes of white scales at
or near the middle (Figs. 119, 120, 121) 32

Mesonotum without white stripes near middle (Fig. 122) 34

*Includes A. stimulans, excrucians, A. fitchii, and A. increpitus

157

32. Mesonotum with two broad white or brassy-white stripes, separated
    by a bronzy-brown median stripe (Fig. 119) .... <u>Aedes</u> <u>trivittatus</u>

    Mesonotum with one median white stripe 33

33. Mesonotum with median stripe broad and extending back to just
    beyond the middle (Fig. 120) .... <u>Aedes</u> <u>infirmatus</u>

    Median stripe of mesonotum narrow and extending to scutellum
    (Fig. 121) .... <u>Aedes</u> <u>atlanticus</u>, <u>A</u>. <u>tormentor</u>

    34. Mesonotum uniformly dark; abdomen with a continuous white line of
    scales at the sides (a small brown species)(Fig. 118) .... <u>Aedes</u> <u>cinereus</u>

    Mesonotum not uniformly dark, having either one or more dark stripes
    at middle or white scaling at the sides; abdomen without a continuous
    white line at sides 35

35. Sides of mesonotum conspicuously clothed with white or yellowish-
    white scales (Fig. 122) 36

    Sides of mesonotum golden to yellowish-brown; one or two brown stripes
    near middle of mesonotum................. <u>Aedes</u> <u>punctor</u> and related species*

36. Sides of thorax densely covered with broad, flat, silvery-white scales;
    dark portions of legs not speckled with white (Figs. 122, 106)...<u>Aedes</u> <u>triseriatus</u>

    Mesonotum with narrow pale scales at the sides; dark portions of legs
    speckled with white scales (Fig. 113).........................<u>Aedes</u> <u>sticticus</u>

GENUS <u>PSOROPHORA</u>

37. Very large yellowish species; legs shaggy, with conspicuous tufts of
    long, erect scales toward tips of femora and tibiae (Fig. 125). <u>Psorophora</u> <u>ciliata</u>

    Medium sized species; legs not markedly shaggy (Fig. 126) 38

38. Wings with mixed dark and white scales (Fig. 123); hind femora
    with a narrow ring of white scales near apex (Fig. 126)..................... 39

    Wing scales uniformly dark; hind femora without a sub-apical
    ring of white scales 41

    *This group includes several of the northern and western woodland and mountain
    mosquitoes which are very difficult to separate. Some of the more important of
    these are: <u>A</u>. <u>implacabilis</u>, <u>A</u>. <u>pullatus</u>, <u>A</u>. <u>communis</u>, and <u>A</u>. <u>hexadontus</u>.

39. Wings uniformly speckled with black and white scales; first segment
of hind tarsi with a white ring at the middle (Fig. 126)......<u>Psorophora</u> <u>confinnis</u>

Wings with definite areas of white and dark scales (Fig. 123)
first segment of hind tarsi largely pale scaled 40

40. Outer half of front margin of wings with two black spots separated
by an area of white scales; scales of wing fringe arranged in alter-
nating dark and pale groups (Fig. 123) .... <u>Psorophora</u> <u>signipennis</u>

Front margin of wing without black spots; scales of wing fringe
uniform in color .... <u>Psorophora</u> <u>discolor</u>

41. Tarsal segments entirely dark .... <u>Psorophora</u> <u>cyanescens</u>

Hind tarsi with 4th and 5th segments white 42

42. Mesonotum with a broad median longitudinal stripe of dark bronzy-
brown scales, sides covered with broad whitish to pale yellow
scales ....<u>Psorophora</u> <u>horrida</u>

Mesonotum uniformly covered with mixed dark brown and white or
golden-yellow scales .... <u>Psorophora</u> <u>ferox</u>

GENUS <u>CULEX</u>

43. Proboscis and tarsi banded with white (Fig. 111) 44

Proboscis and tarsi entirely dark (Fig. 112) 45

44. Femora and tibiae with narrow longitudinal lines of white scales on
outer sides (Fig. 131). Common west of the Mississippi..........<u>Culex</u> <u>tarsalis</u>

Femora and tibiae without narrow longitudinal lines of white scales
on outer sides. Common in the Pacific Coast States
Fig. 132) .... <u>Culex</u> <u>stigmatosoma</u>

45. Abdomen with white scales at apex of segments, especially
evident at sides (Fig. 127) ....<u>Culex</u> <u>territans</u>*

Abdomen with white or yellow scales at bases of segments, usually
forming distinct bands or lateral spots (Fig. 128) 46

*This species has formerly been known as <u>Culex</u> <u>apicalis</u>.

46. Wing scales broad, especially at front of wing; basal white scaling
of abdomen usually limited to sides very small dark species.....
.................................Culex erraticus, C. peccator, and C. pilosus

Wing scales narrow; broad basal white bands on abdominal seg-
ments; larger species, generally brown in color 47

47. Abdominal segments with distinct basal bands or lateral spots
of white scales (Fig. 128) 48

Abdominal segments with narrow dingy-white basal bands; seventh
and eighth segments almost entirely covered with dingy-yellow
scales .... Culex salinarius

48. Mesonotum with a pair of small white spots near middle........ Culex restuans

Mesonotum without white spots .... Culex pipiens and C. quinquefasciatus

GENUS CULISETA

49. Tarsal segments with white or yellowish-white rings 50

Tarsal segments entirely dark 51

50. Wings with dark spots. Occurs west of the Rocky Mountains
(Fig. 124) .... Culiseta incidens

Wings unspotted. Occurs throughout Northern United States.. Culiseta morsitans

51. A large species with broad lightly scaled wings legs sprinkled with
white scales. Distributed throughout the United States .... Culiseta inornata

A small dark species; wings and legs entirely dark scaled.
Occurs in Eastern United States .... Culiseta melanura

GENUS MANSONIA

52. Hind tibia with a wide pale band at outer third (Fig. 91);
postspiracular bristles absent; occurs throughout United
States .... Mansonia perturbans

Hind tibia without a pale band at outer third; postspiracular
bristles present; occur only in tropical and subtropical por-
tions of Florida and Texas .... Mansonia titillans and indubitans

160

GENUS <u>URANOTAENIA</u>

53. Mesonotum with a median line of metallic blue-purple
    scales; hind tarsi entirely dark; occurs throughout
    Eastern United States .... <u>Uranotaenia sapphirina</u>

    Mesonotum without a median line of metallic blue-purple
    scales; hind tarsi with last segments whitish; occurs only
    in southeastern United States .... <u>Uranotaenia lowii</u>

161
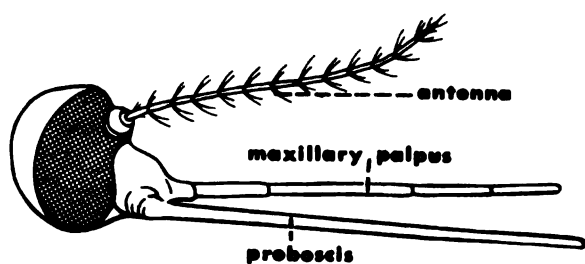
Figure 83
Head of <u>Anopheles</u> female
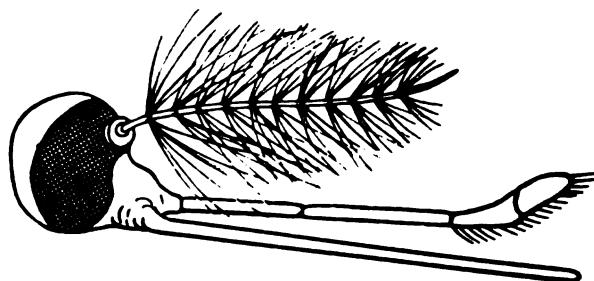
Figure 84
Head of <u>Anopheles</u> male
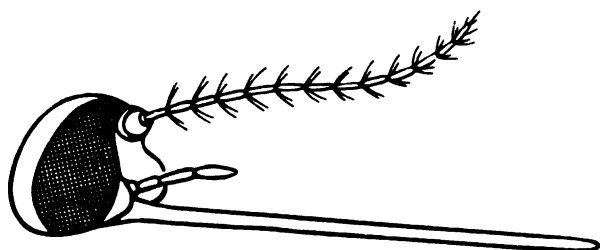
Figure 85
Head of <u>Culex</u> female
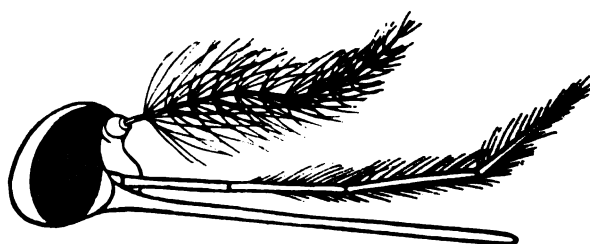
Figure 86
Head of <u>Culex</u> male

DHEW-ATLANTA,GA.

162

PLATE XXVI.

HEAD

THORAX

ABDOMEN

proboscis

antenna

maxillary palpus

eye

occiput

anterior pronotal lobe

mesonotum

scutellum

postnotum

haltere

cerci

I
II
III
IV
V
VI
VII

wing

femur

tibia

LEG

tarsus

1
2
3
4
5
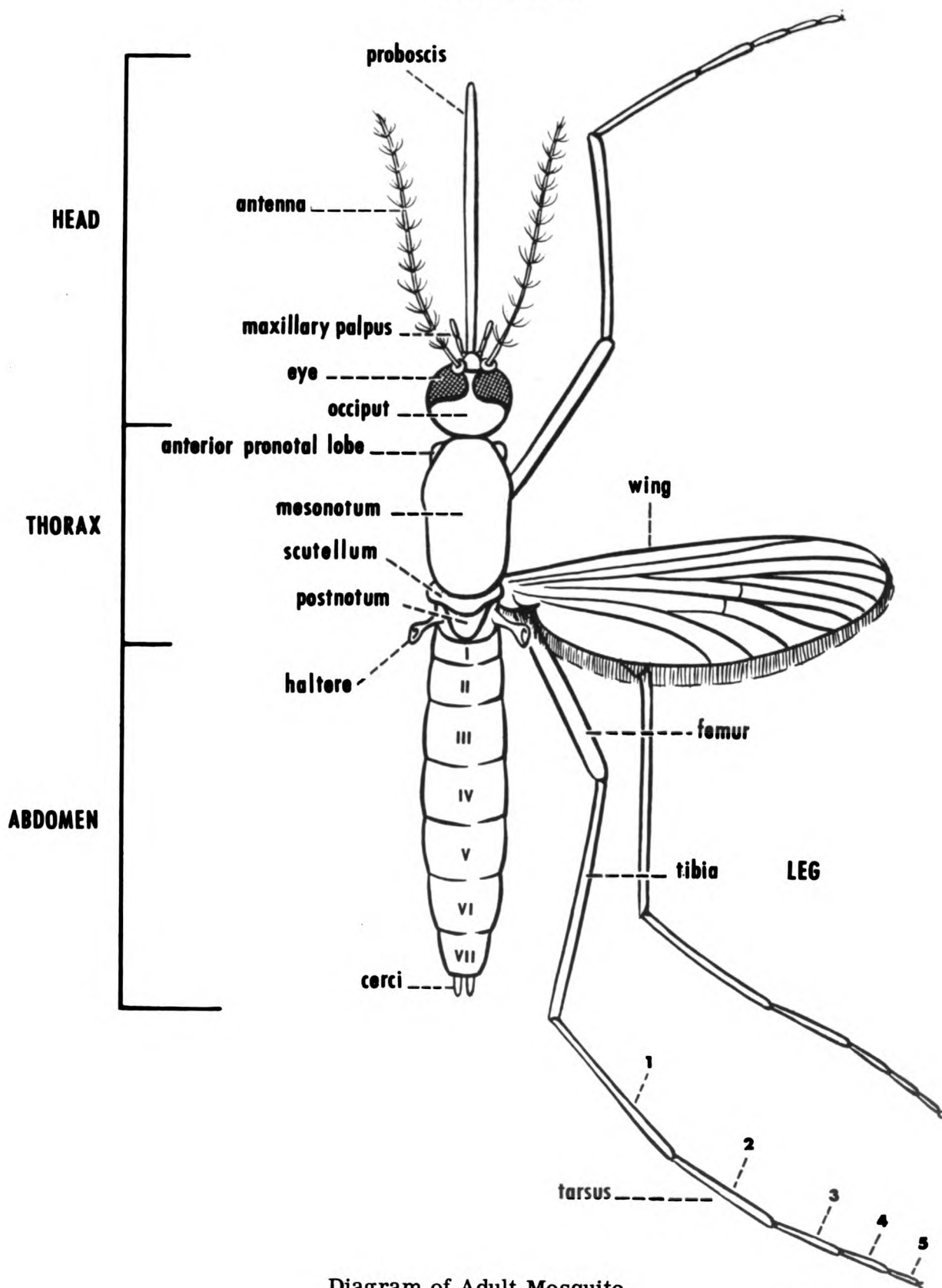
Diagram of Adult Mosquito

163

DHEW-ATLANTA,GA.
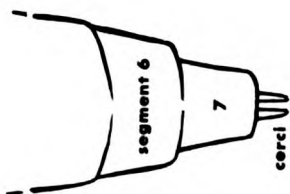
Figure 87.
Pointed abdomen (Aedes)
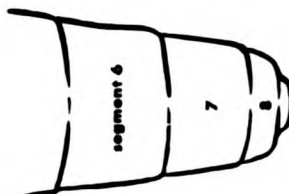
Figure 88.
Blunt abdomen (Culex)

Figure 89.
Broad wing scales (Mansonia)
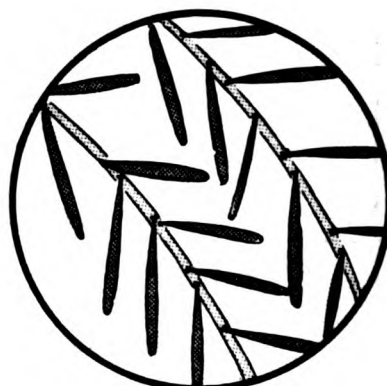
Figure 90.
Narrow wing scales (Culex)

Figure 91.
M. perturbans
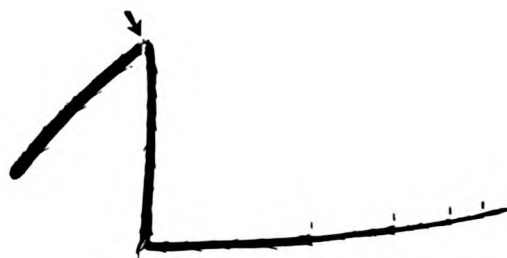
Figure 92.
A. quadrimaculatus

Figure 93.
A. punctipennis

Figure 94.
A. quadrimaculatus

DHEW-ATLANTA, GA.

164
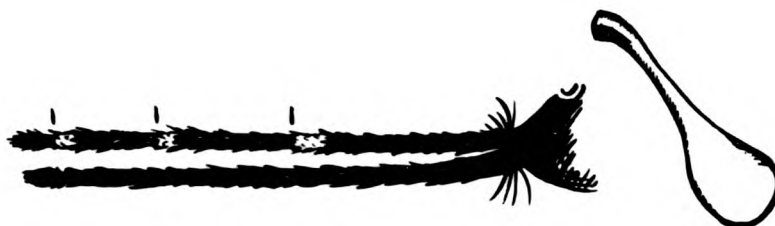
A. walkeri

Figure 95.   Figure 96.

A. quadrimaculatus

Figure 97.   Figure 98.

Figure 99.
A. punctipennis

Figure 100.
A. crucians

Figure 101.
A. pseudopunctipennis

Figure 102.
A. franciscanus

Figure 103.
A. occidentalis

DHEW-ATLANTA,GA.

Figure 104.
A. quadrimaculatus

Figure 105.
Ae. dorsalis
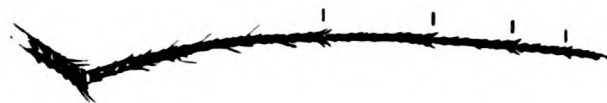
Figure 106.
Ae. triseriatus

Figure 107.
Ae. mitchellae

Figure 108.
Ae. stimulans

Figure 109.
Ae. dorsalis

Figure 110.
Ae. canadensis

Figure 111.
Ae. taeniorhynchus

Figure 112.
Ae. triseriatus

DHEW-ATLANTA,GA.

166
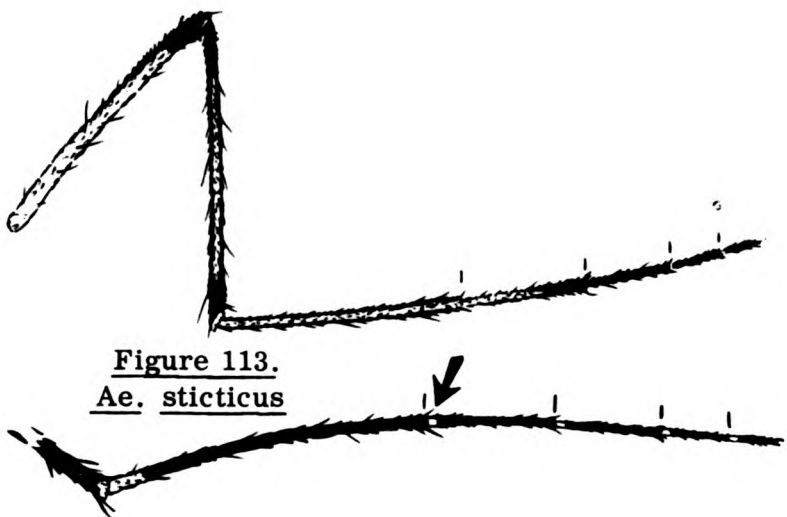
Figure 113.
Ae. sticticus

Figure 113 (A)
Ae. vexans

Figure 114.
Ae. aegypti

Figure 115.
Ae. sollicitans

Figure 116.
Ae. taeniorhynchus

Figure 117.
Ae. vexans

Figure 118.
Ae. cinereus
(side view)

Figure 119.
Ae. trivittatus

Figure 120.
Ae. infirmatus

Figure 121.
Ae. atlanticus

Figure 122.
Ae. triseriatus

CHEW-ATLANTA, GA.

Figure 123.
P. signipennis

Figure 124
C. incidens
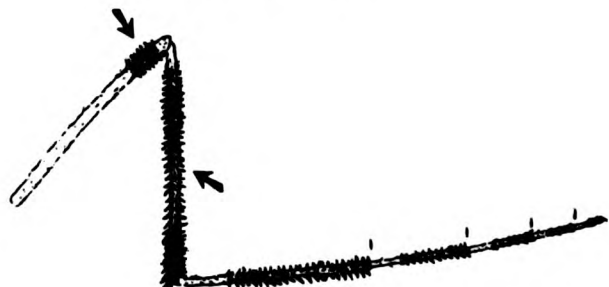
Figure 125.
P. ciliata

Figure 126.
P. confinnis

Figure 127.
C. territans

Figure 128.
C. pipiens

Figure 129.
Culex (Melanoconion) sp.

Figure 130.
Culex (Culex) sp.
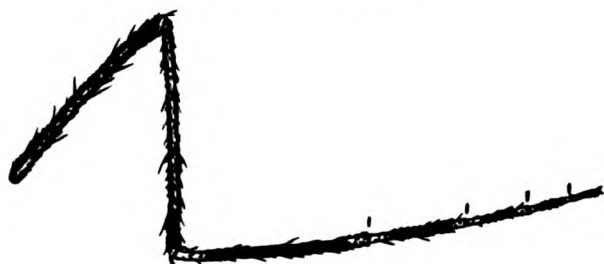
Figure 131.
C. tarsalis

DHEW-ATLANTA,GA.

Figure 132.
C. stigmatosoma

168

PLATE XXVII

PICTORIAL KEY TO SOME COMMON FEMALE MOSQUITOES OF THE UNITED STATES

DHEW-ATLANTA,GA.

PLATE XXVIII.
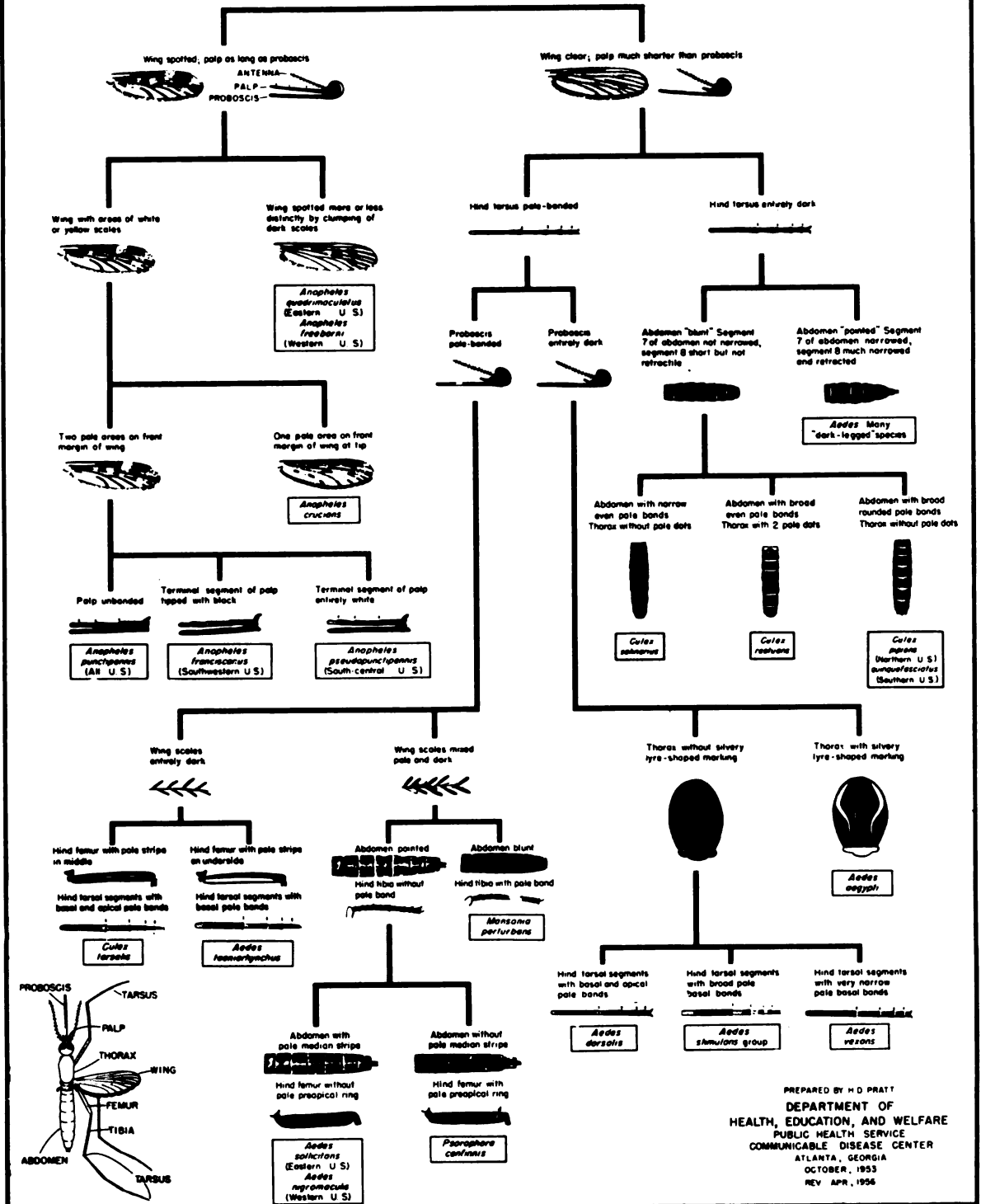
PICTORIAL KEY TO U. S. GENERA OF FEMALE MOSQUITOES

Palpi much shorter than proboscis

Palpi as long as proboscis

ANTENNA
PALPUS
PROBOSCIS

ANOPHELES

Proboscis slender, of about same diameter throughout, never strongly curved downward

Proboscis stout on basal half, outer half tapered and strongly curved downward

TOXORHYNCHITES (Formerly *Megarhinus*)

Abdominal tergites with pale bands or lateral spots on segments; postnotum without setae

Abdominal scales entirely dark dorsally and pale ventrally, the two colors meeting laterally in a straight line; postnotum with a tuft of setae

POSTNOTUM

POSTNOTUM

WYEOMYIA

Wings with second marginal cell at least as long as its petiole

Wings with second marginal cell less than half as long as its petiole

PETIOLE
SECOND MARGINAL CELL

URANOTAENIA

Abdomen "blunt". Segment 7 of abdomen not narrowed, segment 8 short, but not retractile

Abdomen "pointed". Segment 7 of abdomen narrowed, segment 8 much narrowed and retracted

Wing scales narrow or, if broad on distal portion of wing, scales are dark-colored

Wing scales broad, mixed brown and white

Dorsal segments of abdomen with pale scales apically, or if absent, hind tibia with conspicuous, long, erect scales

Dorsal segments of abdomen with pale scales basally, hind tibia never with long, erect scales

TIBIA

PSOROPHORA

AEDES

Antenna not longer than proboscis, first flagellar segment about as long as following segments

Antenna much longer than proboscis, first flagellar segment as long as next two segments

FIRST FLAGELLAR SEGMENT

DEINOCERITES

Mesonotum with fine longitudinal lines of white scales; fourth segment of fore tarsus as long as wide

Mesonotum without lines of white scales, fourth segment of fore tarsus longer than wide

Spiracular bristles present; wing with cross-veins nearly in a line

SPIRACULAR BRISTLES

Spiracular bristles absent; wing with cross-veins separated by their own length

SPIRACLE

CROSS-VEINS

4TH SEGMENT

CULISETA

CULEX

ORTHOPODOMYIA

MANSONIA

170

DHEW-ATLANTA, GA.

PLATE XXIX.

PICTORIAL KEY TO U.S. GENERA OF MOSQUITO LARVAE

GENUS CULEX

General Characteristics

Members of the genus <u>Culex</u>, of which there are about 300 species, are the most common mosquitoes. The scutellum is trilobed; the abdomen is blunt and completely clothed with scales; and postspiracular bristles are absent. The mesonotum is usually not conspicuously ornamented with white. The larvae have a somewhat elongated air tube with well-developed pecten and usually several hair tufts beyond it.

Geographical Distribution

Cosmopolitan in tropical and subtropical regions.

Life Cycle and Habits

The adults are night-feeders and take the blood of man readily. They lay their eggs in rafts, usually with a hundred or more eggs in each. The eggs are deposited in various kinds of containers, or in ground pools, and large permanent bodies of water either in the open or in deep woodland. Favored breeding places are waters containing organic material and even sewage. The eggs hatch in two or three days while still afloat. The larval food varies with the species, but is normally floating or suspended organic matter. After the fourth larval instar the pupal stage appears. This stage does not require more than two or three days.

Relation to Man

Certain species of mosquitoes are the natural vectors of various strains of the ·virus encephalitides. Nearly sixty species of mosquitoes are involved as natural vectors of filariasis (<u>Wuchereria</u> <u>bancrofti</u> [Cobbold]) including 13 species of <u>Culex</u>.

<u>Culex</u> <u>quinquefasciatus</u> (<u>C</u>. <u>fatigans</u>) and <u>C</u>. <u>pipiens</u> (House mosquitoes), are closely related species resembling each other very strongly. The proboscis, thorax and abdomen are brown. The abdominal segments have basal white cross bands of scales joining lateral basal triangular patches. <u>C</u>. <u>quinquefasciatus</u> is found throughout tropical and sub-tropical regions, while <u>C</u>. <u>pipiens</u> is found in the north temperate regions as far as Ethiopia. They are both house mosquitoes, breeding prolifically in artificial containers such as water barrels, tin cans, catch basins, and septic tanks, drains and sewage disposal areas, as well as in polluted pools on the ground. They lay their eggs in clusters or floating rafts, of 200 to 400 each. The incubation period requires one or two days, and the larval period 8 to 10 days, depending on the temperature. The adult emerges from the pupa in about two days. They are not strongfliers, and do not migrate far.

172

PLATE XXX.

ANTENNAL HAIR TUFT

PREANTENNAL HAIR TUFT

LOWER HEAD HAIRS

UPPER HEAD HAIRS

SUBAPICAL
HAIR TUFTS

AIR TUBE
(SIPHON)

VENTRAL
HAIR TUFTS

PECTEN TEETH
(Enlarged)

COMB SCALES

(Enlarged)

DORSAL PLATE
(SCLEROTIC PLATE)

DORSAL HAIR TUFTS

VENTRAL BRUSH
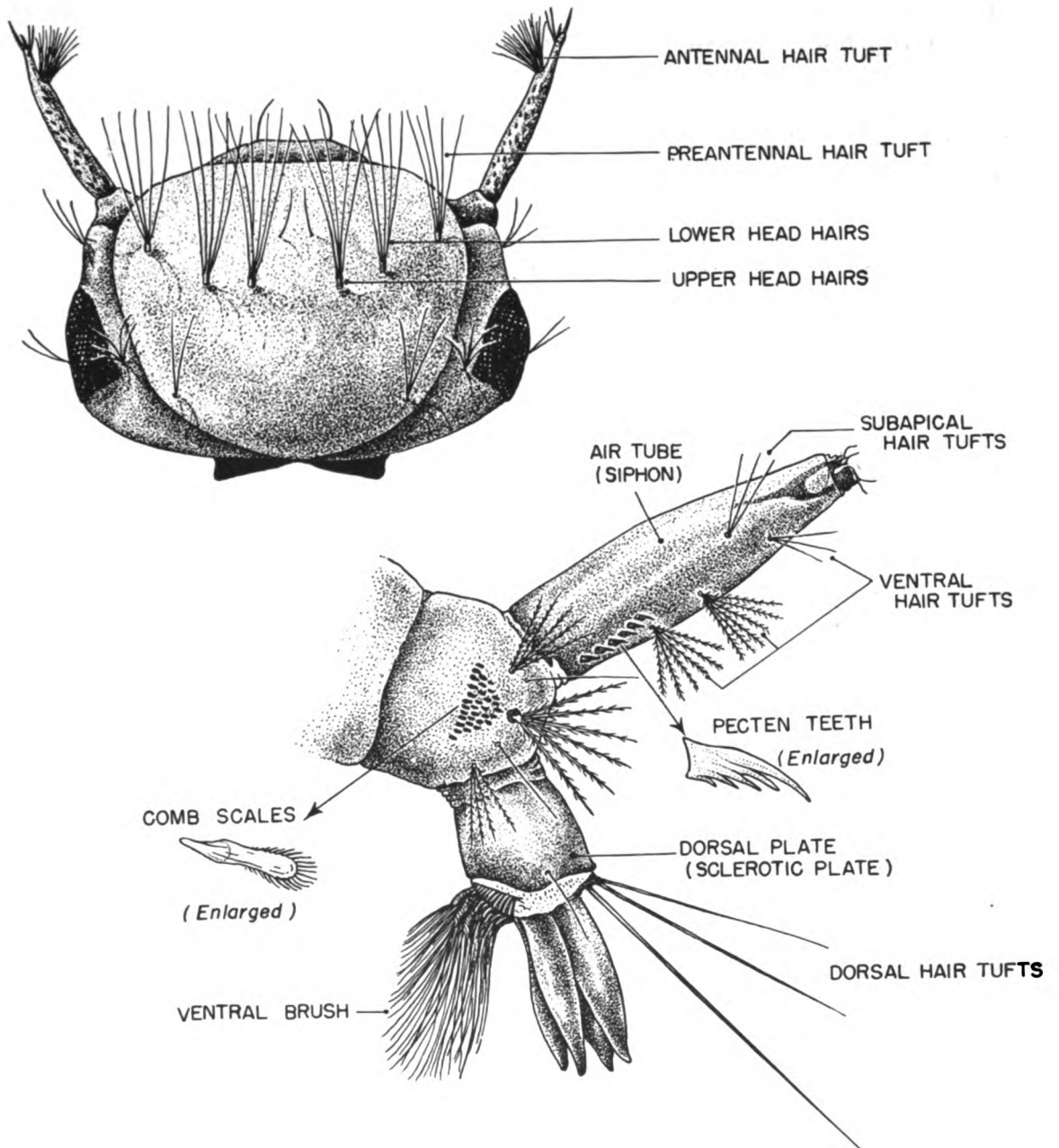
Larva of Culex quinquefasciatus

173

Central Nervous System Viral Infections: The St. Louis strain of encephalitis in epidemic form has a high mortality rate in the Western United States. It is a virus disease which affects the central nervous system. Natural infections have been found in the mosquitoes Culex pipiens, C. tarsalis, C. quinquefasciatus, and Aedes dorsalis (Meig.). Several species have been shown experimentally to transmit the virus as has also the tick Dermacentor variabilis. The chicken mite Dermanyssus gallinae (DeG.), is a natural vector. Domestic fowl and other birds harbor the disease.

Japanese B. Encephalitis: This disease is found in China, Japan, the Southwest Pacific islands and the Maritime Provinces of the U.S.S.R.. It is another virus causing epidemics with fatalities, transmitted mainly by Culex tritaeniorhynchus. Experimentally C. quinquefasciatus and C. annulirostris Skuse and Aedes togoi (Theob.) are satisfactory vectors. Aedes chemulpoensis Yamada is reported to be a vector in North China. The virus is more common in mammals than in birds.

Western Equine Encephalitis: The Western Equine strain of North America is a disease of horses, which also affects man. Three thousand cases were recorded in 1941 with 10 per cent mortality. Culex tarsalis is considered to be the most important vector, although other species of Culex as well as Anopheles freeborni Aitken and Culiseta inornata (Willistron) have been found infected in nature. Other species have proved to be good vectors experimentally. It has been reported that the virus has been demonstrated in the tick Dermacentor andersoni, the mite Dermanyssus gallinae and the hemipteron Triatoma sanguisuga.

West Nile Virus: This disease of Uganda and Egypt is transmitted in Egypt by species of Culex and experimentally by Aëdes aegypti.

Bancroft's filariasis, Wuchereria bancrofti: Bancroft's filariasis occurs in nature in the tropical and subtropical areas of the world except in the United States. Various species of mosquitoes transmit the filarial worms from person to person. There is a developmental period of about ten days in the mosquito. The periodic form is transmitted by Culex quinquefasciatus and C. pipiens or by species of Anopheles. Aëdes togoi is reported to be a vector in Japan and Aëdes pseudoscutellaris Theob. in the Samoan-Fijian area.

General Characteristics

The genus <u>Aedes</u> includes some 500 different species and is the largest single genus of mosquitoes. They can be distinguished from most other common mosquitoes by the tapered end of the abdomen and the projecting cerci; by the presence of post-spiracular bristles and the absence of spiracular bristles. The eggs of most <u>Aedes</u> are not laid on or in water but in various areas such as on the ground along dry margins or at the bottoms of dried-out pools, ponds, marshes, swamps, or above the water level on the edges of containers. Here they remain unhatched until submerged by water. In some of the northern species, the eggs will not hatch the same season even if submerged; thus, these species usually emerge in one great brood the following spring. Other species breed continuously throughout the year. The larvae have a short stout breathing tube with a single pair of hair tufts beyond the pecten. While many <u>Aedes</u> are important pest species, only a few are of primary concern in disease transmission. These important disease vectors all belong to the subgenus <u>Stegomyia</u> and are highly ornamented forms with conspicuous silver or white markings on the thorax, abdomen, and legs.

Geographical Distribution

Cosmopolitan, from the arctic to the tropics.

Life Cycle and Habits

While most <u>Aedes</u> species breed in temporary rain pools, floodwater, and tidal marshes, those species which are of greatest medical importance are totally different in their choice of breeding sites. These larvae, while originally occurring in tree holes or other natural cavities, have in many cases largely transferred to artificial containers of various types in the vicinity of man's habitations. This is especially true of <u>Aedes</u> <u>aegypti</u> and·to a lesser extent of the other species. They are not found in naturally occurring ground pools, an important consideration in their control.

The black, oval eggs are laid on the sides of water containers, usually just above the water line. These containers may dry out completely, and the eggs may remain dormant for weeks or even months. When the containers are refilled or their water levels raised, the eggs are flooded and hatch almost immediately.

The larva develops in 6 to 8 days under favorable conditions and changes into the pupa, from which the adult emerges 2 days later. Thus, the total life cycle may be completed in 9 to 12 days.

The adults are avid biters, feeding throughout the day, especially in the early morning and in the late afternoon, and are usually very common about buildings and

other shelters. They do not fly more than a few hundred yards; hence, when they become troublesome, the breeding source can usually be found near by. This is in strong contrast to other Aedes species, especially the salt marsh forms which may migrate 20 to 40 miles from their breeding grounds.

Relation to Man

Three species of Aedes (Stegomyia) are particularly well known because of their ability to transmit important tropical diseases. Aedes aegypti, a highly domestic species, is the important cosmopolitan vector of urban yellow fever and of dengue. Aedes albopictus (Skuse) is an oriental species, proven to transmit dengue in the Philippines and elsewhere in the Oriental region. Aedes scutellaris (Walk.) is typically Australian in distribution, and its several varieties are distributed throughout the South Pacific islands. They are probably important dengue vectors wherever they occur in numbers (Plate XXXI). Aedes pseudoscutellaris is the principal vector of nonperiodic filariasis in the Samoan-Fijian area. Several other species of Aedes, as well as Culex, are involved as vectors of human encephalitis.

Identification

The three important species of Aedes can be separated by thoracic markings of the adult, but larval distinctions are not so apparent. The lyre-shaped silvery markings on the mesonotum of Aedes aegypti are distinctive of that cosmopolitan species. In both Aedes albopictus and Aedes scutellaris, including its varieties, a median silver stripe is found on the mesonotum but the pleural markings differ. In A. albopictus, the silver scales on the side of the thorax are arranged in spots, while in A. scutellaris these are arranged in three lines.

The larvae of all three species are very similar, those of A. aegypti differing from the other two in the conspicuous thornlike processes at the base of the lateral thoracic hair tufts and in the conspicuous secondary spines on the comb scales. These characters are not present in A. albopictus and A. scutellaris; hence their separation is difficult on other than geographic grounds or the rearing of adults.

Geographic Distribution of Aedes aegypti, A. albopictus, and Species of the Scutellaris Group

Aedes aegypti (yellow fever and dengue)	World-wide in tropic and subtropic climates
Aedes albopictus (dengue)	Oriental region; also in Celebes, Dutch East Indies, Northern Australia (?), New Guinea (?), Hawaiian Islands (introduced)
Aedes scutellaris and closely related species (some or all may carry dengue)	Australasian region

176

A. hebrideus	Solomon Islands, New Guinea, Palau Islands, Dutch East Indies, Moluccas, Philippines, New Hebrides
A. polynesiensis	Somoa, Fiji, Ellice Islands, Marquesas Islands, Society Islands
A. pseudoscutellaris (bancroftian filariasis)	Fiji
A. tongae	Friendly Islands, Sikiana (Solomons)
A. andrewsi	Christmas Island
A. horrescens	Fiji
A. pernotatus	New Hebrides
A. guamensis	Marianas
A. hensilli	Carolines
A. alorensis	Lesser Sundas
A. paullusi	Sangir Island, Philippines
A. quasiscutellaris	Solomon Islands
A. marshallensis	Marshall Islands, Gilbert Islands
A. riversi	Okinawa, Ryukyu Islands

Yellow Fever: This disease is now found only in South and Central America and Africa. Aedes aegypti transmits the urban form from man to man. After a blood meal from an infected individual the mosquito does not become infective for 10 to 12 days while the virus is multiplying. At high temperatures this period is considerably reduced. The insect obtains the virus only during the first 3 to 5 days of the patient's illness.

Jungle or sylvan yellow fever of South and Central America is found in monkeys and other animals of the forest. Mosquitoes of the genus Haemagogus are the vectors, breeding in the tree tops and rarely leaving the forest. Humans become infected by this mosquito when they invade the jungle. When such infected individuals enter a city or town, Aedes aegypti takes over, transmitting the disease from man to man, often starting an epidemic.

The jungle type of fever has moved westward from Eastern Panama, across that country, through Costa Rica, and northward through Nicaragua to Honduras in the last ten years.

In Africa a form of yellow fever is transmitted to man by Aedes simpsoni Theob. and from monkey to monkey by A. africanus Theob.

Other species of Aedes are known to be capable of transmitting the virus of yellow fever, as well as some species of the genera Anopheles, Culex, Eretmopodites and Mansonia.

PLATE XXXI.

DIAGNOSTIC CHARACTERS FOR DISTINGUISHING
SOME MEDICALLY IMPORTANT AËDES

LYRE-SHAPED
MESONOTAL
MARKINGS

MEDIAN
MESONOTAL
STRIPE

AËDES AEGYPTI

**AËDES ALBOPICTUS
AND AËDES SCUTELLARIS**

WHITE SCALES
IN PATCHES

WHITE SCALES
IN TWO LINES

AËDES ALBOPICTUS

AËDES SCUTELLARIS

METATHORACIC LATERAL
SPINES RATHER
CONSPICUOUS

METATHORACIC LATERAL
SPINES RATHER
INCONSPICUOUS

COMB SCALE

COMB SCALE

AËDES AEGYPTI

**AËDES SCUTELLARIS
AND AËDES ALBOPICTUS**

178
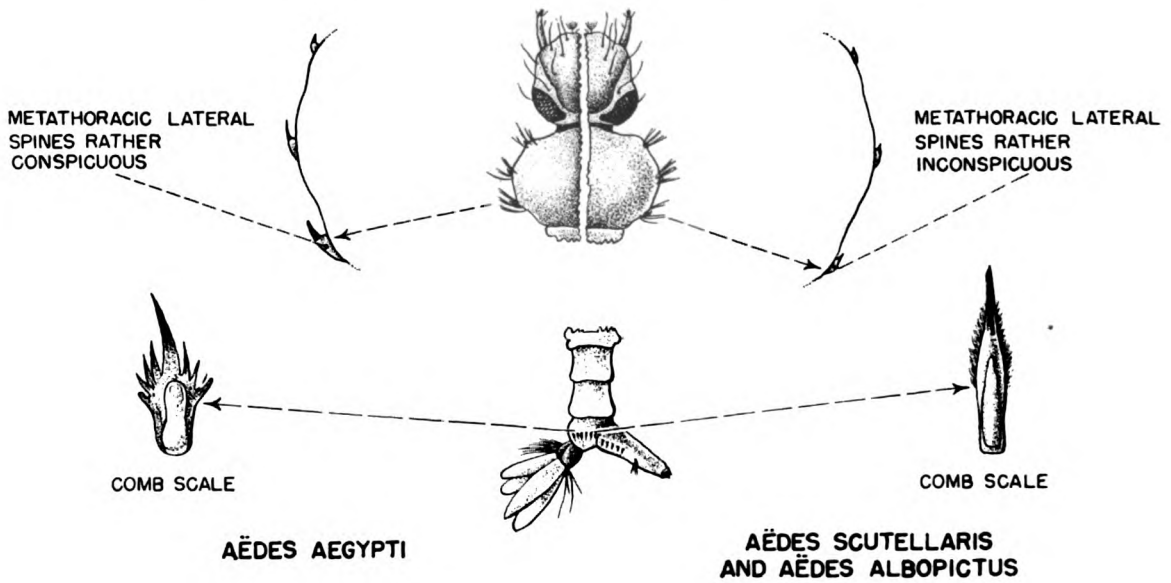
Central Nervous System Viral Infections: Some of the viral diseases transmitted by <u>Aedes</u> have been mentioned under those discussed with the genus <u>Culex</u>. Species of <u>Aedes</u> and <u>Mansonia</u> <u>perturbans</u> (Walk.) have been found to be the natural vectors of Eastern Equine encephalomyelitis. In addition <u>Aedes</u> have been implicated in the transmission of West Nile virus, Semliki Forest encephalitis, Rift Valley fever, and Ilheus encephalitis.

Dengue, or Breakbone Fever: This is another virus disease which is transmitted by <u>Aedes</u> <u>aegypti</u>, <u>A</u>. <u>albopictus</u>, and <u>A</u>. <u>scutellaris</u>. The disease is world wide in warm climates wherever these species of mosquitoes breed. The mosquito becomes infected by biting a dengue patient during the first three days of his illness. The virus multiplies from 8 to 11 days before the mosquito becomes infective. There is no known animal reservoir of the disease.

<div align="center">

GENUS ANOPHELES

</div>

General Characteristics

Members of the genus Anopheles are characterized by their spotted wings; evenly rounded, crescent-shaped scutellum; the long palpi in the female; the absence of scales on the first abdominal tergite; and their peculiar habit of "standing on their heads" when resting. The larvae have a rudimentary breathing tube and lie close under the surface of the water, suspended from it by special palmate hairs on the dorsal surface of the abdomen. They feed primarily on floating material. The eggs are laid singly and bear so-called "floats."

Relation to Man

From the standpoint of human disease, the anophelines are the most important mosquitoes, largely because they are the exclusive vectors of <u>human malaria</u>, the most important single infectious disease of man. In some parts of the world (India, Africa, Melanesia) they are also important transmitters of <u>filariasis</u>.

Life Cycle and Habits

Rate of Development: Most anopheline species require approximately 8 to 14 days for their development from egg to adult under optimum conditions. A longer time is required at low temperatures and under unfavorable food conditions. Thus <u>Anopheles</u> <u>quadrimaculatus</u> requires only 7.3 days at 31° C. (88° F.), while at 12° C. (54° F.) it requires 65.5 days, and below 7° C. (45° F.) it does not develop at all. Rate of larval development is very important in timing control measures.

Feeding Habits: Most anophelines readily attack man, but some of them unquestionably prefer other mammalian blood and are thus at least partially <u>zoophilic</u>. With these forms, there is considerable evidence that the presence of the larger domesticated animals near human abodes may reduce their attacks on man.

Anophelines feed characteristically at dusk or at night, although many species will

<div align="center">179</div>

feed on cloudy, humid days or in heavy shade; and occasionally, rare individuals will bite even in bright sunshine.

Flight Habits: Anopheles quadrimaculatus, the principal vector of malaria in the Southeastern United States, and Anopheles farauti Laver., the important vector in the South Pacific islands, evidently have an "effective" flight range for malaria transmission of 1 mile or less. Thus, if the breeding of these two species within 1 mile of any particular, inhabited place is prevented, no malaria transmission will occur in that place. In North Africa, on the other hand, some varieties of Anopheles maculipennis Meig. are thought to have an effective flight range of several miles. Certanly no "magic mile" should be relied upon blindly, but rather the flight range of each species in each region in which the control is being done should be investigated in the literature and verified by observation or experiment as the control work progresses.

Hibernation: In temperate regions, members of the genus Anopheles usually overwinter as adults in cellars, caves, tree holes, and barns. Anophelines overwintering in warm stables and homes may play an important though circumscribed role in the transmission of malaria.

Longevity of Adults: Preliminary observations on caged individuals of Anopheles farauti would place the length of life of females at about 35 days (temperature and humidity unstated); of males, at about 2 weeks. Other species have been estimated to live from 30 days to 3 months in nature, and anophelines have been kept alive in the laboratory for as long as 8 months.

Larval Habits and Habitats: Larvae of the genus Anopheles are found in a great variety of breeding areas. The pools covered with "green scum," which the unsophisticated point out with a shudder as "dreadful malaria holes," are known now not to be the only source of anopheline breeding. A study of the anopheline fauna of the whole world reveals that some species of Anopheles will breed in almost any conceivable water collection. Some species have a wide range of habitats, while others are very restricted in their breeding.

. The great majority of anopheline species probably prefer the comparatively pure, standing, fresh water of pools, ponds, marshes, and swamps, but there are many exceptions to this rule. Some few species, like Anopheles subpictus Grassi in the Netherlands Indies, are said to prefer polluted water; A. maculatus Theob. in the Orient breeds in swift-flowing streams; A. barberi Coq. and A. bellator Dya breed only in water-holding plants or in the water held in rot holes in trees; and the Oriental A. asiaticus Leicester breeds in cut bamboo stalks. On the other hand, the larvae of A. farauti in the South Pacific have been found in almost every type of fresh and brackish water inhabited by mosquitoes. Its breeding places range from margins of large lakes to hoofprints and an occasional tin can; from margins of swift streams to stagnant swamps; from densely turbid water to crystal-clear springs; from relatively cool water to hot springs; from pools and streams with dense vegetation to puddles with no apparent plant growth; from open, sunlit areas to shaded pools and even wells.

180

<u>Precipitation and Seasonal Cycle</u>: The effect of precipitation on anopheline breed-
ing is most evident in regions where rainfall is largely limited to certain seasons of
the year and where the important anopheline is a rain-pool breeder. The rains result
in a great increase in the number and size of surface pools which persist for some
time after the period of maximum rainfall. Usually then, a maximum production of
pool breeders occurs just after the peak of the rainy season. This is well illustrated
by the seasonal incidence of <u>Anopheles faraути</u> in the South and Southwest Pacific.

In areas where breeding of the local vector is more limited to streams, the larg-
est numbers are usually produced during the dry season when the rains and heavy
flushing floods subside and a more stable stream flow is established.

<u>Anopheles faraути</u>, breeding in both pools and streams, is commonly encountered
along stream margins during the dry season, but in the rainy season the larvae are
flushed from their protected breeding places by frequent heavy floods. Thus this
species is abundant in pools during the rainy season, but it is rarely found in those
streams subject to frequent floods until the dry season.

When periods of maximum precipitation and temperature coincide, temporary
water accumulations will probably be the important anopheline production areas.
Where dry summers are the rule, the breeding will be restricted to permanent water.

Identification of Anophelines

Whenever there is any question as to the exact identity of species involved, such
material may be sent to the Commanding Officer, Naval Medical School, National
Naval Medical Center, Bethesda 14, Maryland, for examination. Instructions for
collecting, preparing, and shipping such material are given in the discussion of ento-
mological technics, section IV.

For Information and Diagnosis of Species of Anopheles consult the following:

1. Bonne-Wepster, J., 1953. The Anopheline Mosquitoes of the Indo-Australian
   Region. J. H. deBussy Co., Amsterdam, 504 pp.

2. Boyd, M. F., 1949. Malariology. A Comprehensive Survey of All Aspects
   of this Group of Diseases from a Gobal Standpoint. (Vol. 1, Section III
   Definitive Hosts), W. B. Saunders Co., Philadelphia.

3. Carpenter, S. J. and W. J. LaCasse, 1955. Mosquitoes of North America
   (North of Mexico). University of California, Berkeley and Los Angeles,
   360 pp.

4. Horsfall, W. R., 1955. Mosquitoes, Their Bionomics and Relation to
   Disease. Ronald Press Co., N.Y.

5. Lane, J., 1953. Neotropical Culicidae, 2 vols., University of São Paulo, Brazil, Vol. 1, 548 pp.

6. Ross, E. S. and H. R. Roberts, 1943. The Mosquito Atlas, Parts I and II, 88 pp.

7. Russell, P. F. and L. E. Rozeboom, and A. Stone, 1943. Keys to the Anopheline Mosquitoes of the World with Notes on Thier Identification, Distribution, Biology, and Its Relation to Malaria. The American Entomological Society, Academy of Natural Sciences, Philadelphia Lancaster Press, Inc., Lancaster, Pa. 152 pp.

8. Senevet, G. and L. Andearelli, 1955. Les Anopheles de L'Afrique du Nord et du Bassin Méditerranéen, P. Lechevalier, Paris.

9. Simmons, J. S. and T.H.G. Aitken, 1942. The Anopheline Mosquitoes of the Northern Half of the Western Hemisphere and of the Philippine Islands. Army Medical Bulletin No. 59, 213 pp.

PLATE XXXII

ANOPHELINE LARVAL CHARACTERS
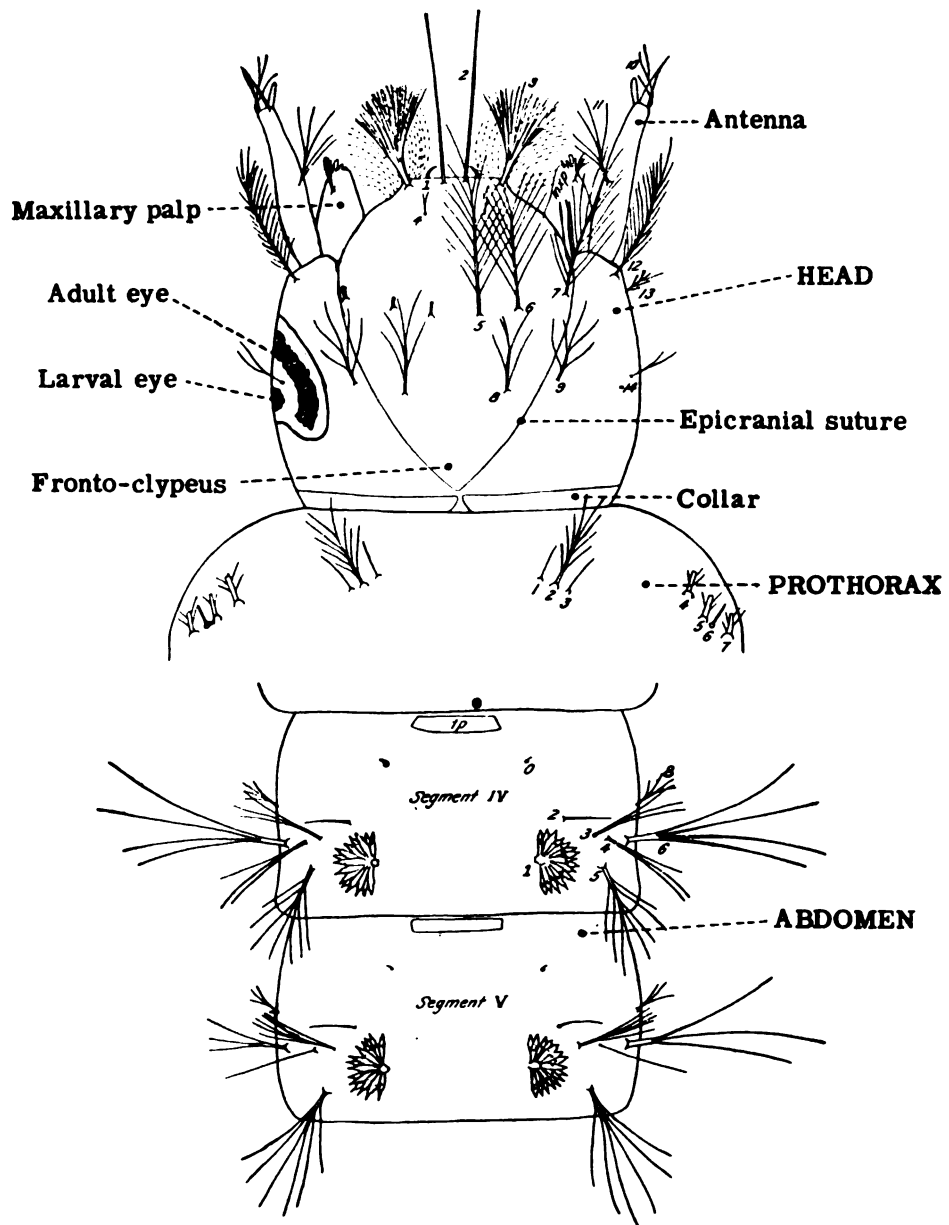
HEAD		PROTHORAX	ABDOMEN
Clypeal hairs	Sutural hairs	Submedian hairs	Abdominal hairs
1. preclypeal	8. inner sutural	1. inner submedian	0. anterior
2. inner clypeal	9. outer sutural	2. middle submedian	submedian
3. outer clypeal		3. outer submedian	1. palmate
4. postclypeal	Antennal hairs		2. antepalmate
	10. terminal antennal	Lateral hairs	3-5. sublateral
Frontal hairs	11. antennal	4-7. lateral	6-8. lateral
5. inner frontal	12. basal antennal		
6. mid-frontal	13. sub-basal antennal		
7. outer frontal			
	Orbital hairs		
	14. orbital		

183

PLATE XXXIII.

ADDITIONAL CHARACTERS OF ANOPHELINE LARVAE

POSTERIOR PLATE PRO-
DUCED INTO A LONG
FILAMENT

(Anopheles darlingi)

ANTERIOR PLATE PRODUCED INTO A
SINGLE LONG FILAMENT

Posterior
lobes
fringed with
hairs

(Chagasia bathanus)

Anterior plate

Spiracle

Lateral flap

Median plate

Posterior plate

COMB OR PECTEN
TEETH
(Sub equal)

RESPIRATORY APPARATUS

COMB OR PECTEN
TEETH
(Long & short)
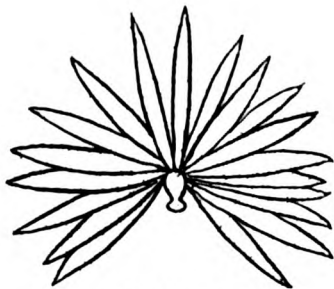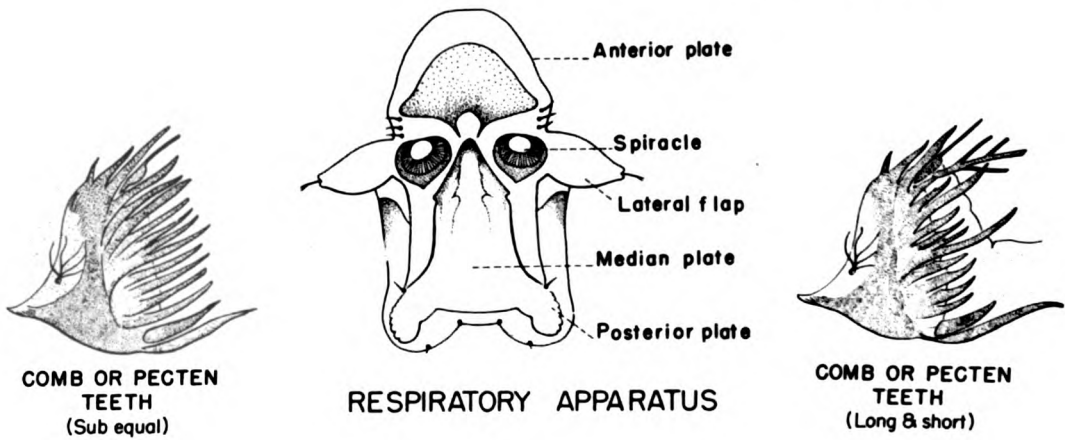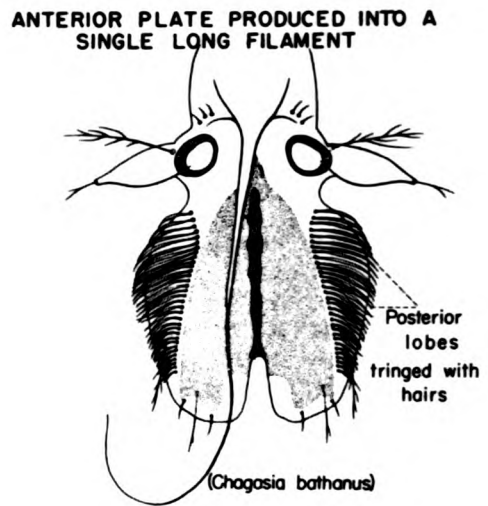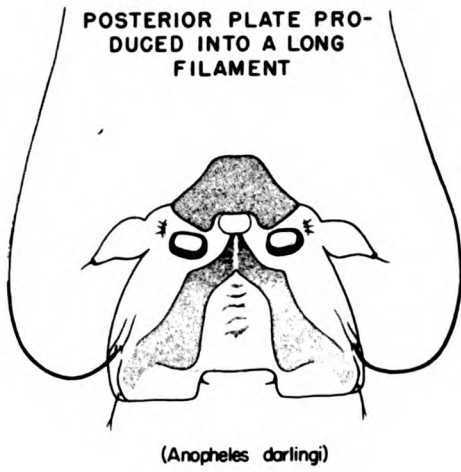
LANCEOLATE
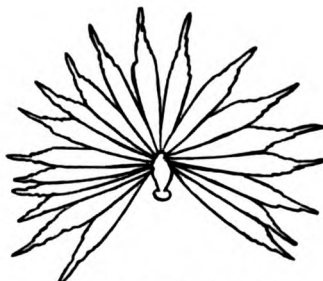
SERRATE - TIPPED
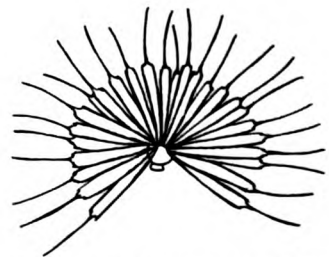
FILAMENTOUS-TIPPED

PALMATE HAIRS

184

PLATE XXIV.

PICTORIAL KEY TO U.S. ANOPHELINE LARVAE

outer clypeals sparsely feathered

outer clypeals densely branched

outer clypeals bare

outer and inner clypeals sparsely feathered on tip, inners close

outer and inner clypeals usually feathered nearly to base, inners widely separated

antennae spiculed, frontal hairs plumose

antennae bare, frontal hairs short and bare

ATROPOS
(Salt water of Atlantic and Gulf Coasts)

ALBIMANUS
(Lower Rio Grande valley of Texas)

PSEUDOPUNCTIPENNIS
(South Central U.S.)

BARBERI
(Tree holes of eastern U.S.)

inner clypeals width of basal tubercle apart

inner clypeals close

fresh water breeder

brackish water breeder

occipitals 6 – branched or more

occipitals 5 – branched or less

hair "O" small and single, or missing

hair "O" large and multiple

only 3 pairs well-developed palmates (on seg. IV, V & VI)

5 or 6 pairs well-developed palmates

5 or 6 pairs well-developed palmates

hair "2" on 4th seg. usually single, 5 or 6 pairs well-developed palmates

hair "2" on 4th seg. usually single, palmates dwarfed except on seg. IV, V & VI

hair "2" on 4th seg. usually triple, palmates small or missing except on seg. IV, V & VI

hair "2" on 4th seg. usually single

hair "2" on 4th seg. usually double, sometimes single or triple

hair "2" on 4th seg. single, inner clypeals feathered at tip

hair "2" on 4th seg. multiple, inner clypeals bare

QUADRIMACULATUS
(Eastern U.S.)
A.m. *aztecus* from Mexico keys out with *quadrimaculatus*, but hair "2" is branched.

BRADLEYI
(Brackish marshes Atlantic & Gulf Coasts)

GEORGIANUS
(Southeastern U.S.)

OCCIDENTALIS
(Northern U.S. and Pacific coast)

PUNCTIPENNIS
(All of U.S.)
and
FREEBORNI
(western U.S.)

WALKERI
(Eastern U.S.)

CRUCIANS
(Eastern U.S.)

after U.S.P.H.S.

185

PLATE XXXV

ADULT ANOPHILINE CHARACTERS
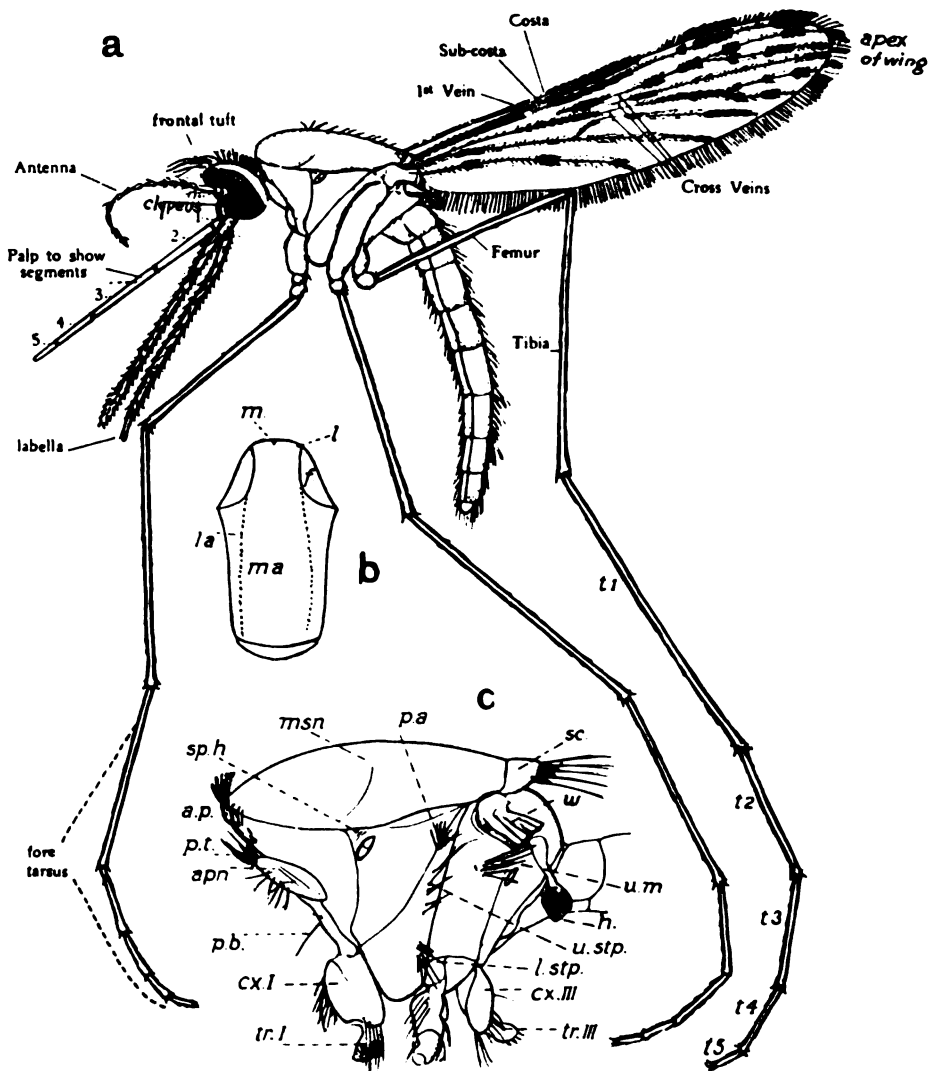
Diagrams showing nomenclature of parts in adult Anopheles. a. Whole insect (female) in side view, showing main parts of body. b. Upper surface (dorsum) of thorax. m.a., median area; l.a., lateral area; f., fossa; m., median and l., lateral positions on anterior promontory where scales are commonly attached. c. Side of thorax, showing areas, bristles, etc. a.p., anterior promontory; apn., anterior pronotal lobe; cx. I, front coxa; cx. III, hind coxa; h., haltere; l.stp., lower sternopleural or mesepisternal bristles; p.a., prealar tuft of bristles; p.b., propleural bristle; p.t., pronotal scale tuft; sp.h., spiracular hairs or bristles; tr. I, front trochanter; tr. III, hind trochanter; u.stp., upper sternopleural or mesepisternal bristles; u.m., upper mesepimeral bristles; w., base of wing.

186

PLATE XXXVI.

PICTORIAL KEY TO U.S. FEMALE ANOPHELINES

PALP PROBOSCIS
ANTENNA

Palps as long as proboscis,
Scutellum evenly rounded.
Wing usually spotted

SCUTELLUM

GENUS
ANOPHELES

HALTERE

KNEE
SPOT

HIND
TARSUS

Wings with areas of
white or yellow scales

Wings entirely
dark-scaled

Two pale areas on
front margin of wing

One pale area on front
margin of wing at tip

Wings clear
-unspotted

Wings spotted more or
less distinctly by clump-
ing of dark scales

**CRUCIANS
GEORGIANUS
BRADLEYI**
See "Pictorial Key to
Anopheline Larvae" for
separation in that stage.

Thoracic bristles long
about one-third the
width of thorax

Thoracic bristles normal
shorter than one-third
the width of thorax

Some specimens of
atropos have faintly
spotted wings. These
are distinguished from
other anophelines by
the absence of light
knee spots.

Hind tarsus entirely
dark-scaled

Hind tarsus with
broad white band

BARBERI
(Eastern U.S.)

ATROPOS
(Atlantic and
Gulf Coasts)

ALBIMANUS
(Lower Rio Grande
valley of Texas)

Palp with narrow white bands
haltere knobs golden-yellow

Palps unbanded
haltere knobs dark

Palp banded

Palp unbanded

WALKERI
(Eastern U.S)

PUNCTIPENNIS
(All of U.S.)

Coppery-colored fringe

No fringe spot

Terminal segment of
palp entirely white

Terminal segment of
palp tipped with black

OCCIDENTALIS
(Northern U.S. and
Pacific Coast)

West of the Rockies

East of the
Rockies

These two species are indistinguishable as adults

PSEUDOPUNCTIPENNIS
(Southwestern U.S.)

FRANCISCANUS
(South-central and
Western U.S.)

FREEBORNI
(Western U.S.)

QUADRIMACULATUS
(Eastern U.S.)

after U.S.P.H.S.

In the life cycles of Sporozoa there is an alternation of generations - a sexual cycle, sporogony, during which multiplication occurs after union of the two sex cells; and an asexual cycle, schizogony, during which there is multiplication without previous fertilization. In some Sporozoa both cycles occur in the same host. Parasites of the Order Haemosporidia have adapted themselves to a life in the blood cells. For members of the Family Plasmodiidae, sporogony takes place in mosquitoes and schizogony in the reticulo-endothelial and tissue cells (i.e. pre- and exo-erythrocytic stages) and in the red blood cells (erythrocytic stage) of vertebrates. Details given apply to the human parasites.

Sexual Cycle (sporogony)-in the Mosquito

When a person who is a carrier of malaria is bitten by a female anopheline mosquito, parasites are taken up with the blood. The mosquito becomes infected if both sex forms of the Plasmodium were present in adequate numbers. The ingested male and female gametocytes (sexually differentiated cells capable of producing gametes) become altered in the stomach of the mosquito and are known as gametes. The microgametocyte (male cell) undergoes a development known as exflagellation during which its nucleus divides, each part taking a filament of cytoplasm. These are microgametes (male gamete) which break away and seek out the female gamete. The macrogametocyte (female cell) prepares for fertilization by extruding part of its chromatin. The microgamete penetrates this macrogamete and the chromatin of the two fuses. The zygote (fertilized cell), thus formed, becomes elongate and motile and is then known as the ookinete, some 12 to 24 hours after the mosquito has ingested the blood. The ookinete migrates through the stomach wall of the mosquito and forms the oöcyst (the encysted form) between the epithelium and the muscular layer. This requires about 40 hours. The oöcyst grows and undergoes reorganization. In 4 or 5 days, thousands of sporozoites have developed in each oöcyst sporogony (sexual reproduction by the development of spores). When fully developed, the oöcyst ruptures and releases the sporozoites (the form resulting from the division of the oöcyst) into the body cavity of the mosquito. These migrate to the tissues, many reaching the salivary glands, and the mosquito is infective (Plate XXXVII).

The approximate time required for completion of the sexual cycle, or extrinsic incubation period, in the three well-known species under optimum conditions is given below. Both humidity and temperature are important factors, high humidity being necessary. Below 15° C. sporogony is inhibited. Once sporozoites have matured, they will survive at lower temperatures. Although mosquitoes have been found to be infective for 3 months, it is thought that the period of infectiveness is somewhat shorter. Those that live unusually long may become noninfective. A mosquito may carry more than one species of malaria at the same time or may become reinfected. There may be few or many oöcyts developing at the same time. The asexual forms ingested by the mosquito are destroyed.

188

Species	Length of Sexual Cycle
P. falciparum (Welch).................	10-12 days at 30° C.
P. malariae (Laveran)	18-21 days at 22° C.
P. vivax (Grassi and Felett)	8-10 days at 25° C.

Asexual Cycle (schizogony)-in Man

When an infected mosquito bites man sporozoites are introduced with its salivary fluid thus initiating the development of the parasite prior to entry into red blood cells (pre-erythrocytic development). Subsequent development up to the time of actual appearance of the parasite in the red blood cells is incompletely known in the case of malaria in man. The sporozites gain access to the circulatory system and after an hour or so apparently invade the liver parenchymal cells where for a period of several days they develop and multiply producing schizonts (a form developed from the trophozoite in which the nucleus has divided or split) and finally micromerozoites (cells resulting from division of a mature schizont).

The erythrocytic cycle begins when the micromerozoites enter the red blood cells. Trophozoites (the vegetative or feeding stage) are the youngest forms recognized in the erythrocytes. These are composed of a nucleus and cytoplasm containing a vacuole frequently referred to as signet-ring form. The trophozoites develop into schizonts which form merozoites that are liberated from the red cells into the blood stream as the red cells disintegrate. Within a short time the young trophozoites may again be found in the blood cells.

After several generations of the asexual cycle, gametocytes are developed. Their production is sometimes referred to as sporogony in man since these are the forms which start the sexual cycle in the mosquito. The gametocytes develop from merozoites which are indistinguishable from other merozoites. Young gametocytes are usually not found in the blood smears since their development in all species takes place in the blood vessels of the bone marrow and spleen. Macrogametocytes are more numerous than microgametocytes.

189

PLATE XXXVII.

LIFE CYCLE OF MALARIAL PARASITES
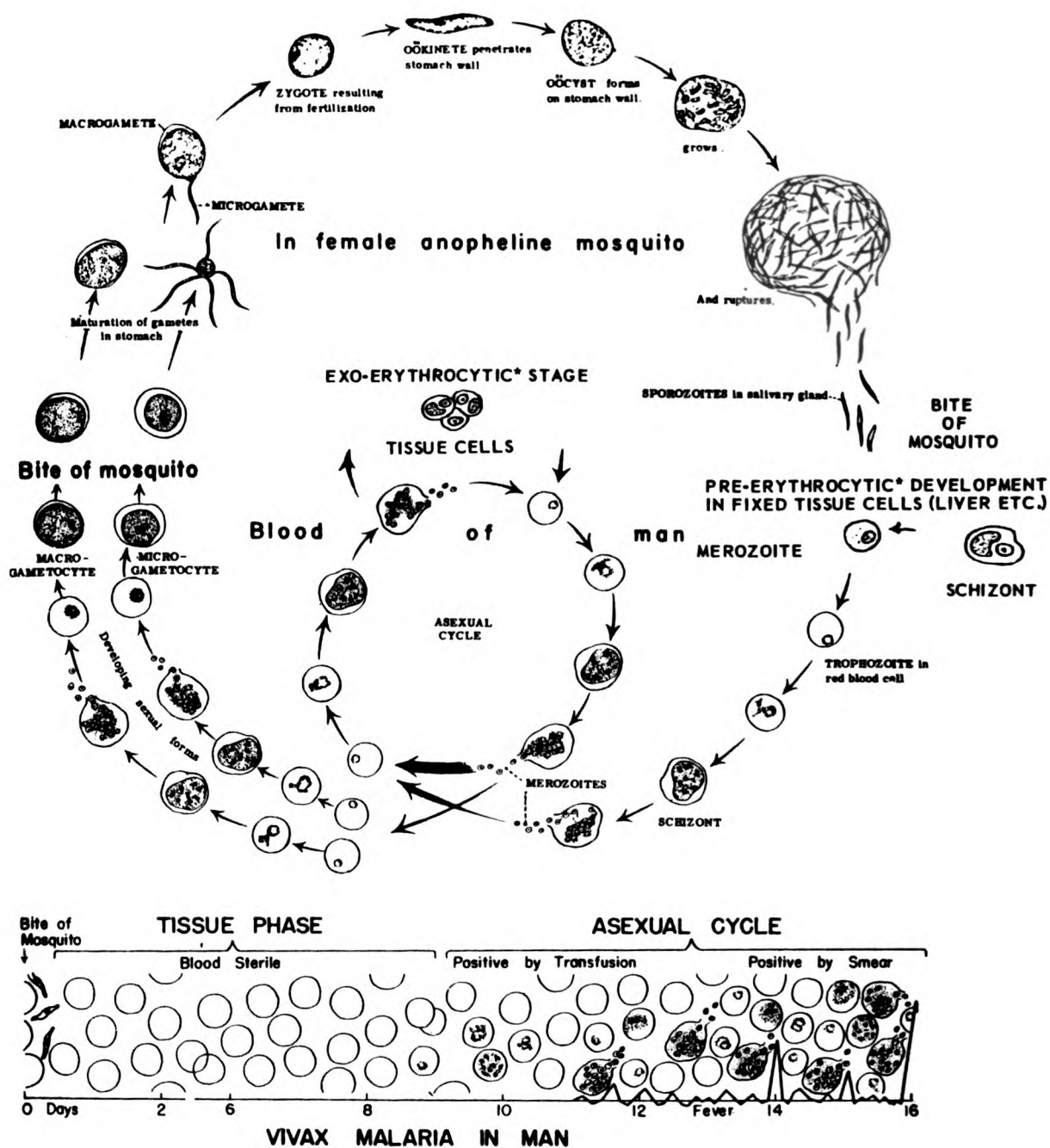
*Detailed development of these stages is not yet known

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192

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193

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CONTROL OF MALARIA VECTORS

REGIONS OF COMMON OR TYPICAL BREEDING PLACES OF MOST IMPORTANT MALARIA - TRANSMITTING SPECIES OF ANOPHELES MOSQUITOES – PRINCIPAL CONTROL MEASURES

BREEDING PLACES → / REGION ↓	Brackish water swamps, pools, and marshes, usually open to sunlight	Fresh water swamps, pools, shaded, under jungle or swamp vegetation	Fresh water, open to sunlight	Large rivers, fast or slow, grassy edges (instream bed pools)	Small streams, ditches, seepages, moderate current, grassy sides, clear water	Hill streams, free from grass, very slow current, clear water	Hill streams, free from grass, moderate current, clear water	Irrigation channels, with bays or pockets, grassy sides, average current	Shallow seepage, clear water, from irrigation or streams	Reservoirs, impounded water, ponds, bayous, lakes	Rain water pools, especially if containing algae. Rock pools	Springs, small pools, hoof-prints	Rice fields	Open wells	Tanks in open air, or dark wells in houses	Artificial containers, cans, coconut shells, gourds, bottles, etc.
South Pacific Islands	A. farauti / A. punctulatus	A. farauti / A. punctulatus	A. farauti / A. punctulatus	A. farauti	A. farauti	A. farauti	A. farauti	A. farauti	A. farauti	A. farauti	A. farauti	A. farauti / A. punctulatus		A. farauti		A. farauti
Netherlands Indies	A. sundaicus / A. subpictus	A. umbrosus (also in brackish water) / A. leucosphyrus			A. maculatus (in sunlight) / A. umbrosus / A. barbirostris	A. minimus flav-irostris / A. maculatus (in sunlight)	A. maculatus (in sunlight) / A. kochi	A. aconitus	A. aconitus	A. kochi	A. subpictus (usually polluted)	A. leucosphyrus	A. aconitus / A. sinensis			
Philippine Islands		A. minimus flav-irostris			A. minimus flav-irostris	A. minimus flav-irostris	A. minimus flav-irostris		A. minimus flav-irostris				A. minimus flav-irostris			
Malaya	A. sundaicus	A. umbrosus	A. umbrosus		A. maculatus (?) / A. barbirostris	A. maculatus	A. maculatus	A. aconitus	A. aconitus	A. philippinensis	A. philippinensis	A. aconitus	A. annularis	A. umbrosus		
Burma	A. sundaicus				A. minimus / A. maculatus	A. maculatus	A. maculatus	A. minimus	A. minimus	A. philippinensis		A. philippinensis	A. minimus / A. philippinensis			
India	A. sundaicus	A. sundaicus	A. superpictus / A. fluviatilis	A. superpictus / A. fluviatilis	A. minimus / A. fluviatilis	A. superpictus (Baluchistan)	A. culicifacies / A. minimus	A. fluviatilis / A. philippinensis (in open ponds)	A. fluviatilis / A. philippinensis	A. culicifacies / A. stephensi / A. minimus			A. culicifacies / A. annularis	A. stephensi / A. culicifacies / A. minimus	A. stephensi	
Ceylon			A. culicifacies (in sand pools)		A. minimus / A. fluviatilis	A. minimus		A. culicifacies	A. culicifacies		A. minimus	A. minimus	A. minimus / A. culicifacies / A. varuna	A. culicifacies	A. stephensi	
Thailand Indo-China	A. tessellatus		A. culicifacies / A. jeyporensis	A. culicifacies / A. jeyporensis	A. minimus / A. culicifacies / A. maculatus / A. barbirostris	A. minimus / A. maculatus	A. macul lac	A. culicifacies	A. culicifacies	A. minimus (?)		A. minimus / A. culicifacies / A. stephensi	A. minimus / A. culicifacies / A. stevensis			
China	A. tessellatus / A. sinensis		A. culicifacies / A. superpictus	A. culicifacies / A. superpictus	A. minimus / A. maculatus	A. minimus / A. maculatus / A. pattoni	A. minimus / A. stevensis	A. minimus / A. maculatus	A. minimus / A. stevensis	A. sinensis	A. sinensis	A. stevensis / A. minimus / A. pattoni	A. stevensis / A. minimus / A. pattoni			
Near East	A. sacharovi		A. jeyporensis	A. jeyporensis	A. superpictus	A. multicolor		A. superpictus	A. superpictus	A. gambiae / A. superpictus / A. claviger	A. sargentii	A. sargentii			A. stephensi / A. claviger	
North Africa	A. labranchiae	A. algeriensis / A. pharoensis	A. superpictus	A. superpictus	A. superpictus			A. labranchiae	A. labranchiae	A. labranchiae	A. sargentii	A. sargentii	A. labranchiae			
Central and South Africa	A. gambiae melas	A. funestus / A. nili / A. macul. nyerlandii	A. funestus / A. nili / A. macul.	A. funestus / A. nili	A. gambiae / A. funestus	A. gambiae / A. moucheti	A. gambiae	A. gambiae	A. gambiae	A. gambiae / A. funestus / A. hancocki	A. gambiae / A. funestus / A. hancocki	A. gambiae / A. funestus / A. hancocki		A. gambiae		A. funestus / A. gambiae
Italy Balkans Spain	A. labranchiae (also sep. atroparvus in Spain and Portugal) / A. sacharovi		A. superpictus	A. superpictus	A. superpictus	A. superpictus		A. superpictus	A. superpictus	A. labranchiae / A. labranchiae atroparvus (in Spain and Portugal)	A. sacharovi	A. sacharovi / A. maculipennis	A. labranchiae / A. labranchiae atroparvus (in Spain and Portugal)			
Russia Eastern Europe	A. sacharovi / A. maculipennis	A. darlingi	A. superpictus	A. superpictus	A. sacharovi / A. superpictus	A. sacharovi / A. superpictus	A. maculipennis	A. maculipennis / A. superpictus	A. maculipennis / A. superpictus	A. albitarsis / A. darlingi	A. sacharovi / A. maculipennis	A. sacharovi / A. maculipennis	A. albitarsis			
South America	A. albimanus / A. albitarsis	A. darlingi		A. darlingi	A. darlingi	A. albitarsis	A. albitarsis	A. albitarsis	A. albitarsis / A. darlingi	A. darlingi / A. bellator (also in bromeliads)	A. albimanus	A. albimanus	A. albimanus			A. funestus / A. gambiae
Central America West Indies	A. albimanus	A. punctimacula / A. darlingi		A. pseudopunctipennis (pools, algae)	A. pseudopunctipennis	A. pseudopunctipennis		A. pseudopunctipennis	A. pseudopunctipennis	A. darlingi / A. albimanus	A. albimanus	A. albimanus	A. albimanus			
Southern N. America	A. quadrimaculatus	A. quadrimaculatus	A. quadrimaculatus	A. quadrimaculatus	A. quadrimaculatus	A. quadrimaculatus	A. quadrimaculatus	A. pseudopunctipennis	A. pseudopunctipennis / A. quadrimaculatus	A. quadrimaculatus	A. quadrimaculatus	A. quadrimaculatus	A. quadrimaculatus			
Western N. America						A. freeborni		A. freeborni		A. freeborni	A. freeborni					

EFFECTIVE MOSQUITO CONTROL MEASURES APPLICABLE TO ABOVE TYPES OF BREEDING PLACES *

Until adequate mosquito control is established, especially in tropical areas, fairly good malaria control may be obtained by hand-catching of adult Anopheles in quarters or tents, and by night and morning.	Open marsh ditching. Dikes, tide gates and ditches. Filling by hydraulic and natural. Increase salt content of water by flooding with sea water. Decrease salt content of water by flooding with fresh water. Larvicides.	Drainage. Natural and artificial fill. Clearing to let in sunlight. Pollution with decaying vegetation. Larvicides. Shading	Drainage. Natural and artificial fill. Clearing to let in sunlight. Pollution with decaying vegetation. Larvicides.	Channelization of river stream. Controlled silting of stream bed sides. Clear away or poison grass. Larvicides.	Subsoil drainage. Open drainage with dense shade. Flushing. Larvicides fish. Larvicides.	Flushing. Continuous drip oiling. (Dense shade against A. maculatus.)	In Malaya, dense shade, subsoil drainage. Elsewhere flushing, channelling of stream bed. Larvicides.	Intermittent irrigation. Restbag canal banks. Clear vegetation away. Larvicides fish. Larvicides.	Restriction of excessive use of irrigation water. Larvicides fish. Vertical drainage. Pump out low areas and return water to irrigation canals. Larvicides.	Clear reservoir bottom of all vegetation before filling. Fluctuating water levels. Larvicidal fish. Clear vegetation from banks. Larvicides.	Subsoil drainage. Drainage. Larvicides. Pyrethrum spray on springs used for drinking water.	Intermittent drying. Carefully level paddies before planting. Keep banks clear of vegetation. Modifying water. Larvicidal fish. Larvicides. Oiled sawdust	Fill in, if not in use. Cover with mosquito-proof cover. Larvicidal fish. Oiling with light oil such as kerosene.	Mosquito-proof covers, or increased access. Frequent change of water with surface disturbance. Larvicidal fish. Larvicides.	Remove, empty, and/or destroy useless containers, shells, cans, gourds, etc. Empty water out of boats periodically. Larvicides

195

* USE EVERYWHERE AND ALWAYS – Intelligent selection of sites for dwellings, barracks, and camps, to avoid vicinity of Anopheles breeding areas. Avoid also, if possible, proximity to native villages or houses. Effectively screen quarters if possible, otherwise, use bed nets.

SECTION III.

MOSQUITO SURVEY AND CONTROL
(with special emphasis on malarial control)

MOSQUITO SURVEY AND CONTROL
(with special emphasis on malarial control)

INTRODUCTION (NEED FOR CONTROL)

Relationship and Importance to Human Welfare

Mosquitoes cause more discomfort and misery to human existence than any other family of arthropods. They have always plagued mankind, and have prevented his utilization of many fertile and productive regions. Although man is host to this parasite for only short periods of time, mosquitoes take their toll as certainly and methodically as any enemy of man. They have undermined the welfare of many countries from the an ancient to the modern. They are worldwide in distribution and in most tropical and subtropical areas huge swarms may be produced in small quantities of water. Directly and indirectly they have caused more casualties in many campaigns than have weapons of war.

The annoyance and irritation caused by their presence and bites is sufficient reason for man's attack against them. Mosquito bites normally produce only temporary discomfort in most people, but in some even one bite will cause a violent reaction. Their role in causing misery by their direct attacks on man is minor when compared with the part they play as disseminators of death-dealing diseases.

Vectors of Disease

Malaria has been considered the most important infectious disease of man. Malaria has been estimated by some authorities as the direct or indirect cause of more than one-half the deaths of the world's population. It is prevalent throughout the tropics and subtropics, except in islands of the Central Pacific. The primary toll exacted by malaria is calculated in the value of the lives lost, cost of medical services, loss of man hours, reduced efficiency, lowered resistance to other diseases, and health factors. Of secondary importance are the effects which cause economic damage by preventing the development of agriculture, business, and industry. Property values and the general prosperity are considerably depressed in malarious areas. The total cost annually to the world is difficult to determine.

In the past, malaria was the most important disease in the military. History records many examples where malaria profoundly modified the conduct and outcome of campaigns. There were over 300,000 cases of malaria in the Union Army alone during the Civil War. World War I saw an entire front in Macedonia immobilized for three years. Nearly 80 per cent of the French troops were hospitalized for malaria. British casualties from the disease were almost seven times the number killed, wounded, taken prisoner, or missing. In World War II, malaria was "Enemy No. 2" for the

forces in many areas and caused more casualties than action from Enemy No. 1. It caused great havoc to the troops in the South Pacific, Mediterranean, and the India-Burma theaters before its importance was recognized. Fortunately, Epidemiological Units and Malaria Control Teams were able to bring malaria and other such diseases under control. A peak case rate of 2678 per 1000 per annum in 1942 was dropped to as low as 5 per 1000 per annum in 1944 in some of the most malarious areas of the world.

Malaria is caused by minute protozoans that invade the tissues and red blood cells. There are four distinct species of protozoa that are known to cause the disease in humans. They can be identified on the basis of clinical symptoms and laboratory examinations. The parasites are known as Plasmodium vivax which causes vivax or benign tertian malaria; P. malariae, the agent causing quartan malaria; P. falciparum, the causative agent of aestivo-autumnal, malignant, pernicious, or subtertian malaria; and the rare P. ovale, which causes ovale malaria.

Malaria is transmitted to man, except in rare or experimental cases, only by mosquitoes belonging to the genus Anopheles. Of over 200 species of this genus in the world, only about two dozen are efficient vectors. Most Anopheles are susceptible to the parasite under experimental conditions.

Dengue is an acute, infectious, febrile disease of the tropics and subtropics. It is caused by a filterable virus and is transmitted chiefly by Aedes aegypti and Aedes albopictus. It becomes epidemic at times especially when large numbers of susceptible or "new comers" are exposed to the infection. The disease lasts from three to eight days but is rarely fatal except in the aged and infirm. Convalescence is of long duration. The disease frequently breaks out in explosive epidemics that spread rapidly, especially among new susceptibles or after the disease has been absent for several years. The disease starts suddenly with a high fever, flushed face, and severe prostration. Usually the fever subsides after a short period but returns, accompanied by a transitory rash and "aching bones." Patients frequently suffer great pain in movement of the eyes. At present there is no effective vaccine and no specific treatment.

Due to its explosive nature and high infectivity rate it could play a decisive role in military campaigns, especially to invading forces. In such cases many susceptibles may be exposed to the virus-bearing mosquitoes while the defending forces may have had the disease and recovered. Such was the case in the U.S. forces entering Guam and Sicily during World War II. Fortunately, on Guam, most of the personnel were not incapacitated until the island was "secured."

Yellow fever is an acute, febrile, infectious disease, caused by the filterable yellow fever virus. "Yellow Jack" has been termed one of the most dangerous diseases of man. Its focus originally was the West Coast of Africa but is now found mainly in the Western Hemisphere, especially in South and Central America. The death rate is very high. The incubation period in man normally is three to seven days. The virus is present in the blood stream during the first three or four days after onset.

197

Aedes aegypti, a mosquito of worldwide distribution, is the principal vector in the tropics, although at least thirty-three other species are capable of transmitting the disease. The mosquito vector may obtain the infection up to the fourth day after the onset in man and may remain infected for life. The incubation period in the vector is from 9 to 14 days.

Until recently man was the only known susceptible vertebrate host and Aedes aegypti was considered the only important vector. Control of the disease by reduction or elimination of the vector was usually successful although sporadic outbreaks occurred at widely separated places. It is now known that there are other animals susceptible to the disease in a specialized environment. Forest animals, particularly monkeys, serve as wild reservoir hosts and the vectors are usually tree top breeders and feeders. This sets up an enzootic cycle and is called sylvatic or jungle yellow fever. Man is rarely infected except in the jungle, especially when cutting trees.

Elimination of the wild reservoir host and the tree-breeding vectors seems out of the question for control of the disease. There is no specific drug for eradication of the virus. Control of the disease has been fairly successful by eliminating or reducing the domestic breeder, Aedes aegypti. Vaccination affords a high degree of protection for humans and is being carried out on an extensive scale.

There are two human types of filariasis, sometimes called "elephantiasis," or "mu-mu." Bancroft's filariasis, caused by the tissue roundworm, Wuchereria bancrofti, has a wide distribution throughout tropical and subtropical countries. The adult worms are found in man principally in the lymphatics below the diaphragm. The microfilaria are "sheathed" and exhibit a noxturnal periodicity in the blood stream. A non-periodic type is found in some South Pacific islands. Malayan filariasis, caused by Wuchereria malayi, is found in Southeastern Asia and Southwestern Pacific islands. The adult worms are in the lymphatics, typically above the diaphragm. The young exhibit a partial nocturnal periodicity in the blood stream.

Symptoms of the disease are usually slow in appearing and Europeans seldom show symptoms until after 10 to 15 years in endemic localities. Some troops in the Pacific during World War II, however, developed symptoms in as short a time as three and one-half months. Its military importance stemmed primarily from a psychological point of view. It is characterized by lymphangitis, swelling and redness of the glands, usually in the genitals. Mental and physical depression are pronounced and headache, nausea, and fatigue are common.

There are numerous species of mosquitoes that are capable of transmitting filariasis. The Culex pipiens complex are the most prevalent transmitters of W. bancrofti in cities but many Anopheles are probably more efficient vectors (Anopheles farauti, A. gambiae, A. funestus, A. darlingi). Aedes pseudoscutellaris is the principal vector in Samoa and Fiji. Malayan filariasis is transmitted principally by mosquitoes of the genus Mansonia whose larvae develop attached to roots or stems of aquatic plants.

Encephalomyelitis (brain fever) caused by filterable viruses that attack the central nervous system occur in many parts of the world. In North American there are three strains affecting man that are transmitted by mosquitoes - eastern and western equine and St. Louis encephalomyelitis. Venezuelan and Argentinian strains occur in South America. Japanese "B" and Russian Spring-Summer encephalitis are found in the Far East. Eight distinct strains have been found in Africa. Most of these are mosquito-borne but some are tick- and mite-borne.

The diseases caused by the various strains are similar. Japanese "B" encephalomyelitis will serve as a representative of the diseases. The fatality rate is very high and there is no specific treatment. The disease has a sudden onset with intense headache, stiff neck, and malaise. Nausea, vomiting, and convulsions are common. Patients recovering are usually impaired mentally. Vaccines are relatively ineffective. Epizootic infections in horses or other animals usually preceded human outbreaks especially in epidemics. Culex tritaeniorhynchus is the vector of Japanese "B" encephalitis and Culex tarsalis transmits the North American strains.

Pests and Annoyances

Hoards of mosquitoes can spoil a pleasurable outing, turn a resort paradise into an intolerable hell and rob a hunter or fisherman of all pleasure from such recreation. If such insects can dampen man's enthusiasm for pleasurable endeavors they can certainly play an important role in everyday activities and become a particular problem, especially morale-wise, in work or in military operations. Such interfering annoyances can reduce efficiency profoundly. It is difficult if not impossible to get much needed sleep and rest even when one or two mosquitoes are present. The constant sing of threatening mosquitoes may be as unnerving as the actual bite.

The bites of mosquitoes, regardless of disease organisms transmitted, can cause serious skin irritations. Secondary infections may result from such bites or from scratching the area.

Responsibility for Vector Control

Control of pest mosquitoes in and near military installations, at home or abroad, is essential to comfort, efficiency, and morale of the personnel. Responsibility for so vital a thing as one's health and welfare is primarily an individual one. It is important for the individual to be informed and trained in measures of personal protection. There are numerous situations even in controlled areas where the individual must utilize personal measures of protection. These measures are especially important, and are many times the only protection, in combat situations. Such measures are discussed in "Control Methods."

Command Responsibility

Navy Regulations prescribe the responsibilities of the commanding officer at each activity of the Department of the Navy for measures to insure the health and comfort of his command. Normally, responsibility is delegated to various departments within the command.

SECNAVINST 5420.17, 13 November 1953 outlines the responsibilities and functions of the various offices and bureaus of the Department of the Navy as regards pest control. BUMEDINST 6250.4, 22 December 1954 delineates responsibilities delegated to the Burea of Medicine and Surgery and the Bureau of Yards and Docks in pest control: vector (health) and economic.

Medical Department Responsibilities

The medical department is assigned primary and technical responsibility for recommendations to the commanding officer regarding vector control. Detailed and specific responsibilities are set forth in the Instructions given in Section V. Briefly, the medical department determines the need for vector control, establishes identity, source, and density of vectors, provides instructions regarding proper use of toxic chemicals, and evaluates results of control operations.

Responsibilities of the Bureau of Yards and Docks. (Public Works Departments – Marine Corps Maintenance Departments.)

Intructions in Section V set forth the specific responsibilities of these organizations with regards to pest and vector control. In general the responsibilities include control procedures for all economic pests and operational support of vector control programs.

Special Operating Units

Throughout the Naval Establishment a limited number of Preventive Medicine Units and medical entomologists are available, on a district or area basis, for utilization by commands with significant vector problems. When authorized by BUMED this specialized personnel may conduct such vector survey and control operations as are outlined in the Instructions in Section V.

EVALUATING THE PROBLEM (SURVEYS)

Except in emergencies or certain military operations mosquito control should not be undertaken until investigative studies have established the "why and how" of control. When it is impossible to conduct a survey, the existence of a disease and efficient vectors must then be assumed and all available means of protection and control utilized. As time and conditions permit, a detailed survey should be conducted to determine the incidence of the disease, density of the vectors, and the most effective and economical means of control.

Mosquito surveys, and surveys dealing with mosquito-borne diseases, should be conducted by personnel well trained in the field. The day of the amateur, especially in malariology, is over, if it ever existed. The malaria story during World War II is adequate proof of this fact. Troops, engaged in endemic areas, were accompanied by excellent medical officers yet the malaria rate was appalling. When specialized personnel were utilized the malaria problem was brought under control very rapidly. The Navy has specialized operating units that can be called upon to conduct such surveys. During World War II Epidemiology Units, Malaria Survey Units, and Malaria Control Units were utilized extensively. Preventive Medicine Units are now established in most area commands for this purpose. Such a unit may be composed of a Medical Officer, trained in tropical medicine; Medical Service Corps Officers, who are trained especially in entomology, parasitology, bacteriology or virology, etc., and several specialized technicians.

There may be all degrees of surveys from a reconnaissance over the area in a low flying plane, a drive through the area in a car, to a complete, systematic survey that includes data and recommendations regarding everything related to the problem. A preliminary survey might be conducted satisfactorily by one expert. In any event, the personnel must be expert in collecting data and specimens sufficient to adequately evaluate the problem.

Surveys required for evaluating the need for and formulating recommendations for control procedures are usually divided into two parts: parasite and vector. These surveys may also be in two phases: the preliminary or the basic systematic.

A good map is prerequisite to planning and carrying out a mosquito survey and for use in control operations. If an adequate map is not available one should be made (see Surveying and Mapping, page 253). The best map for this purpose is made of aerial photographs, scaled to 500 feet to the inch. Contour maps are useful for showing general topography. A good map is required for orientation and for location of breeding places and collecting stations in relation to the zone to be protected. If collection figures are indicatd on a large wall map in control headquarters, the data will be readily available for the control teams. Figure 253 illustrates a sketch map of a mosquito control area.

Figure 133.
Sketch map of mosquito control area showing location of collection stations

202

Preliminary or Reconnaissance Survey

Frequently, especially under military conditions, control operations need to begin without having all the data that could be collected in a systematic survey. If at all possible, as much information as time permits should be obtained by a preliminary survey. Valuable information on mosquitoes and diseases can be obtained from published records of early surveys, annual reports of public health or agricultural agencies, or even from historical sketches, travel guides or diaries. Intelligence reports should be studied for health conditions in new or inaccessible areas. The preliminary report should include data and recommendations on the parasite index and the first eight items listed for the basic mosquito survey. This is the minimum for adequate preparation and planning for control. More intensive investigations will be made on these items during the basic survey.

Basic or Systematic Survey

A well planned and executed survey is truly a research project and it should be approached with no preconceived idea as to the outcome. The data from the investigation of unknown factors constitute the true situation.

It is mandatory in the military organization to have official sanction to conduct a survey. This may come about by pressure from "above" or it may be an intelligent understanding and desire for improving health and welfare. The latter should be cultivated. It is much more essential to have good public relations in conducting such surveys in a civilian or native population.

Parasite (Malaria) Incidence Survey

A malaria survey is intended to determine the degree and extent of malaria within a population. It may be only a small sample for a preliminary survey or it may be a long-term systematic study which reveals seasonal and cyclic incidences and distribution. Such a survey is important in planning a program and especially so for evaluating the results of control measures.

The ideal parasite index survey would include examination of the blood of each resident of a community. In most instances this is impossible due mainly to the lack of technicians and time. There are several procedures for evaluating the malaria parasite index in a population: the spleen, parasite, hemoglobin, and anemia indices. The first two are the most important and only ones to be discussed here.

Spleen Index. Enlarged spleens are characteristic of malarial infection, especially in children under twelve years of age. Therefore, a splenic survey among the children of a community should give a good indication of the amount of malaria in the population. This is especially useful in preliminary studies. More detailed information could be obtained by making microscopic examination of the blood of children

having enlarged spleens - further - if all in the family were so examined. The data should clearly define the age group in such a survey. Most malariologists use essentially the same technique for palpating the spleen but there are various ways of record-cording the results.

Splenic examinations are best performed with the subject in a recumbent position with the knees flexed and abdomen bared. In some communities, especially primitive ones, it may be advisable to examine the subject while he is standing since the recumbent position may be looked upon with alarm. The examiner, on the subject's right, gently palpates the upper left quadrant of the abdomen with his right hand. Relaxation on the part of the subject is required. When the spleen is not palpable under normal inspiration, full deep abdominal breathing may permit the palpation of a slightly enlarged spleen, just under and above the costal margin.

Boyd's classification divides enlarged spleens into the following categories: PDI (palpable on deep inspiration), No. 1 - at costal margin, No. 2 - from costal margin to half way to the umbilicus, No. 3 - from half-way point to the umbilicus, No. 4 - extending below the umbilicus. (Fig. 134.)
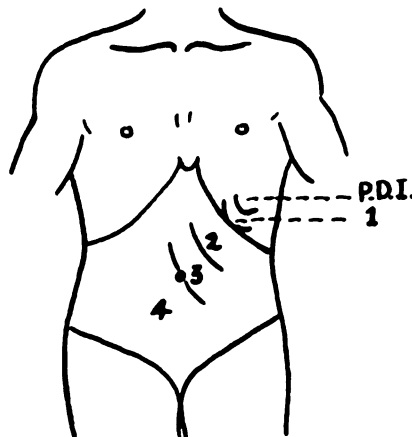
Figure 134.
Classification of splenic enlargement (Boyd)

Parasite Index: There is only one sure way of diagnosing malaria and that is to find the parasites in the body. Since the erythrocytic cycles are found in the red blood cells, stained preparations of the blood are used for diagnosis. The "thick smear" method is preferred since the parasites are concentrated in a small area. Three or four drops of blood are placed on a microscope slide; the drops are mixed, dried, and stained (usually with Giemsa). The red blood cells are "laked" (hemoglobin removed) during staining. Here the concentrated parasites stand out with the white cells against a light blue background. Some workers believe the "thin film" to be better for species identification; however, an experienced technician should have no trouble identifying

the species of malaria in a "thick smear." The "thin film" is a monocellular layer of blood, spread evenly on a microscope slide. The blood is dried, fixed, and stained. The RBC's remain intact. Many workers prepare both thick and thin preparations on the same slide. Infected blood on a thin film showing one parasite in fifty microscopic fields would show from 250 to 500 parasites in the same number of fields in a thick smear. Consult texts on Parasitology for more details on technique.

Appraisal of Malaria Index. When the data on the malaria incidence has been compiled it speaks for itself. If malaria is present it will be evident, and simple arithmetic will show the percentage of the sample that is positive. One can tell at a glance if the population is very malarious or not. However, there is a need for more accurate evaluation in terms of a base-line in relationship to other surveys.

One arbitrary method of expressing the intensity of infection in an area, based on spleen rates, is as follows:

Spleen rate less than 10 per cent - low endemicity.
Spleen rate between 10 and 25 per cent - moderate endemicity.
Spleen rate between 25 and 50 per cent - high endemicity.
Spleen rate over 50 per cent - hyperendemicity.

Hackett suggest an appraisal based on combinations of the blood and splenic examinations as follows:

Both indices (parasite and spleen) low: sporadic cases, spaced situation, low intensity - hypo-endemic .

Parasite but without enlarged spleens: acute malaria in non-immunes, low intensity.

Parasite index less than half the spleen index: low transmission now and recently, with bad years in the past.

Parasite index half the spleen index: an endemic condition fading after a series of mild years, with lessening (or diminishing) transmission.

Parasite index greater than or equal to spleen index (both high): epidemic conditions.- a recent wholly acute situation if the index of children and adults are comparable; an acute excerbation of an endemic situation if the child indices are greater.

Spleen index over 50 per cent: hyperendemic situation, or the remains of one.

The transmission index is the per cent of position blood films of children under one year of age.

Infection in the Mosquito. The natural index of infection in the known or suspected vectors may be determined by dissecting their salivary glands and stomachs and noting the presence of sporozoites in the former and oocysts on the latter. This index is not a valid picture of human malaria species since some Anopheles may transmit avian malaria, but it is helpful in evaluating the total malaria survey. A precipitin test of the contents of the gut of engorged mosquitoes may help distinguish

between the androphilic and zoophilic species. Only females should be dissected since males do not bite and do not become infected.

Surveys of Other Mosquito-Borne Diseases

The need for control of yellow fever, dengue and encephalomyelitis is usually based on clinical findings and morbidity reports. Methods of determining indices of these diseases are very compliaated. The methods for filariasis surveys are somewhat similar to those used above but the obtaining of parasite indices is considerably more difficult. The number of individuals with swollen glands and extremities may be determined, and microfilaria are demonstrable in the blood at certain periods.

The Basic Mosquito Survey

When there is evidence that malaria or other mosquito-borne diseases are prevalent in a community or area, or if mosquitoes are sufficiently numerous to be annoying, a survey should be undertaken to determine the species, source, location, densities, and flight ranges. Frequently such a survey is conducted simultaneously with the disease survey. The more information that is known about the mosquitoes, the more effective and economical the control will be. The basic survey is investigative by nature and should attempt to uncover facts not previously recorded regarding life cycles, breeding habits, feeding preferences, habitat of larvae, and resting places of adults. This is in contrast to the less detailed information needed for preliminary surveys and evaluation surveillance.

Mosquito surveys are intended to estimate the relative abundance of one or more species in an area. Usually an index of the population is obtained through the use of various sampling methods but the absolute population is not determined since this would be difficult, if not impossible, in large areas. The index will serve to indicate fluctuations in densities during survey and control, even though the total population is not known.

Since considerable knowledge of taxonomy, life histories, and habits is required, well trained and experienced personnel must be utilized for basic surveys. If literature on the mosquitoes of the area is available, it should be studied. Unusual and new species may be referred to specialists in taxonomy for identification.

There are many methods and techniques utilized for sampling mosquitoes. One method may be satisfactory for one species but useless with another. Knowledge of habits, preferences, and life-cycles is valuable for employing or devising the best method. It is best to use a combination of methods rather than relying on one method alone. To be of value the information must be recorded in easy-to-use forms.

It is best to begin the survey by sampling the adult mosquito population, since immature stages are more difficult to find. It is not difficult to find adult mosquitoes – usually they will search out any individual within range, and the human disease vectors

206

will most likely be among those finding the individual. Adult collections are valuable in helping locate the immature stages.

Adult Mosquito Survey

Usually there are two principal techniques for capturing any wild animal: searching for and snaring (or shooting) the beast or enticing it into some trap. Generally large numbers can be captured by utilizing the latter method. Some animals are caught in large numbers at roost or in resting areas. It is rather difficult to seek for and capture mosquitoes in natural environments because of their small size and agility. It is much easier to find them in large numbers while at rest, and to utilize their preferences and needs for enticing large numbers to specific collecting stations. The literature may be of help in establishing the best types of stations for a given species. If such information is not available, it should be obtained by a thorough study of the species.

There are several types of collecting stations that may be used for determining the adult mosquito population: daytime resting stations, animal bait traps, light traps, biting-collecting stations, and rarely, insect nets. After selection of the various collection stations, they should be indicated on a map with identifying symbols.

Diurnal (Daytime) Resting Places. Many species of mosquitoes are inactive during the day and may be found resting in dark, cool, and damp environments. If a few ideal resting places are located in or near an area where diurnal resting mosquitoes are prevalent, a large percentage can be collected there. In some areas adequate natural resting places, such as hollow trees (Fig. 135), logs, caves, etc., are to be found. Usually there are some man-made structures such as bridges, culverts, stables, poultry houses, privies and dwellings (Fig. 136), where such mosquitoes can be found. If these structures house persons or animals, the attractiveness of the station is enhanced due to the available blood meal. Artificial resting stations may be provided where others do not exist. The more natural they can be made, the more attractive they will be to the mosquitoes. Large wooden boxes, old barrels, etc. can be utilized to good advantage, especially

Figure 135.
Collection of adult mosquitoes from a natural resting place.

if they are plastered with mud, kept damp and cool, and placed in protected places out of drafts.

Figure 136.
Collection of anophelines in native hut

Several collections should be made from numerous diurnal resting stations under different weather conditions before selection of final collecting stations are made. The mosquitoes collected should be placed in boxes and labeled with pertinent data.

Animal Bait Traps

In most species of mosquitoes, the female requires a blood meal before the eggs will mature. This is the one feature which is responsible for the great damage caused by mosquitoes. These females seek to fulfill this need unrelentingly by attacking the nearest source of blood. Many species have a decided "taste" or preference for certain animals; some prefer man, some horses, cows, birds, even pigs, etc. If the preference of the important vector is known, the preferred animal may be used to good advantage to lure many of the insects into a trap.

The trap must be of sufficient size and strength to keep the animal comfortable and to permit easy access and removal. In some cases the collector must enter the trap to collect the mosquitoes while it is baited. Large areas of each side of the trap should be covered with screen wire and horizontal ingress baffles or "valves" should be placed on at least two sides of the trap (Fig. 137). Most mosquitoes perform a bouncing motion on a screen or crawl in many directions seeking entrance. After attaining their goal, a blood meal, most engorged mosquitoes seek the nearest resting spot. A few species have a drive to escape at dawn and may be found on screens facing the East.

Traps are generally baited before dusk and remain so overnight. Some mosquitoes are active during the day and for such, the traps should be baited during this period.

208
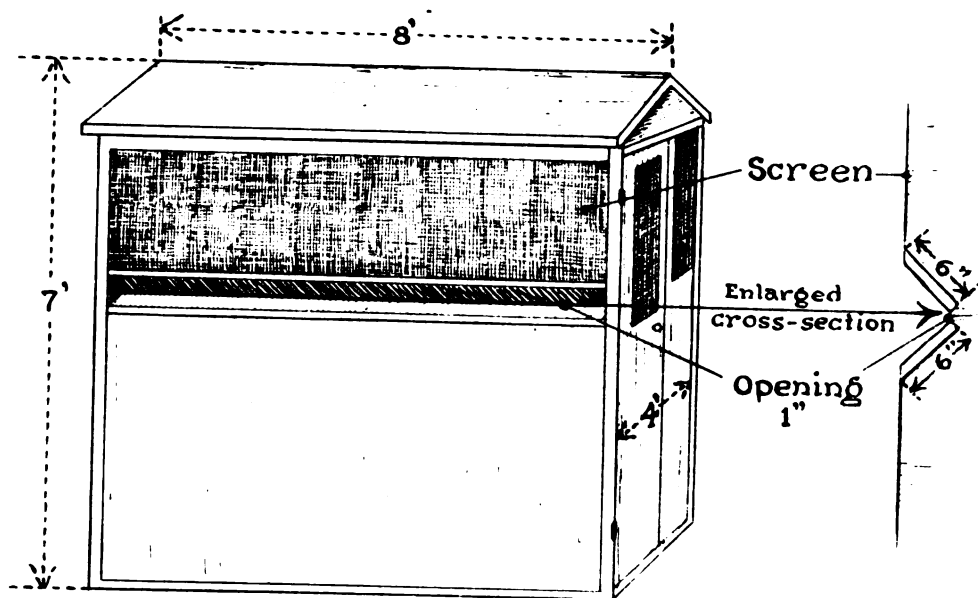
Figure 137.
The Magoon-type bait trap.

There are several methods for utilizing man as bait for mosquito traps and at the same time protecting the individual from the bite of the mosquito. Windows in dwellings may be converted into a screen cage with ingress baffles on the outside to form a window trap. Mosquito nets or jungle hammocks may be provided with a sleeve trap, or a trap may be constructed which will be of sufficient size to enclose a jungle hammock or cot protected with a mosquito net. The bait, usually the collector, sleeps in the protected bed and emerges in the morning to collect the trapped mosquitoes. If such a trap is portable, several areas may be checked at specified intervals.

Some mosquitoes are attracted to carbon dioxide, and small traps may be made to utilize dry ice in place of an animal as bait. Any tin cylinder, 12 inches in diameter by 14 inches deep or larger, fitted with screen funnels at both ends can be used.

Light Traps

Although most mosquitoes shun daylight and are inactive during that period, they are attracted at night to certain types of artificial lights, especially those of low wattage. The New Jersey light trap is used extensively as a collecting station (Fig. 138). This trap is a metal cylinder about 10 inches in diameter by 15 inches long, in which a screen wire cone is mounted with a killing jar attached to the bottom. A small electric fan and a low watt electric light bulb, covered with a conical tin roof, are located above the cylinder. Mosquitoes approaching the light bulb are caught by the down draft from the fan and blown into the screen cone and killing jar. The killing jar contains about 1/2 inch of calcium cyanide, covered with 1/2 inch of sawdust

209

(or cotton), and held in place by a thin layer of plaster of Paris. If live specimens are desired, a bobbinet bag may be substituted for the killing jar. A hardware cloth grid between the light and fan or around the openings at the top will exclude many larger insects attracted to the light. Some traps may be constructed so as to operate from a storage battery. An interval automatic timing device may be used for turning the trap on and off.
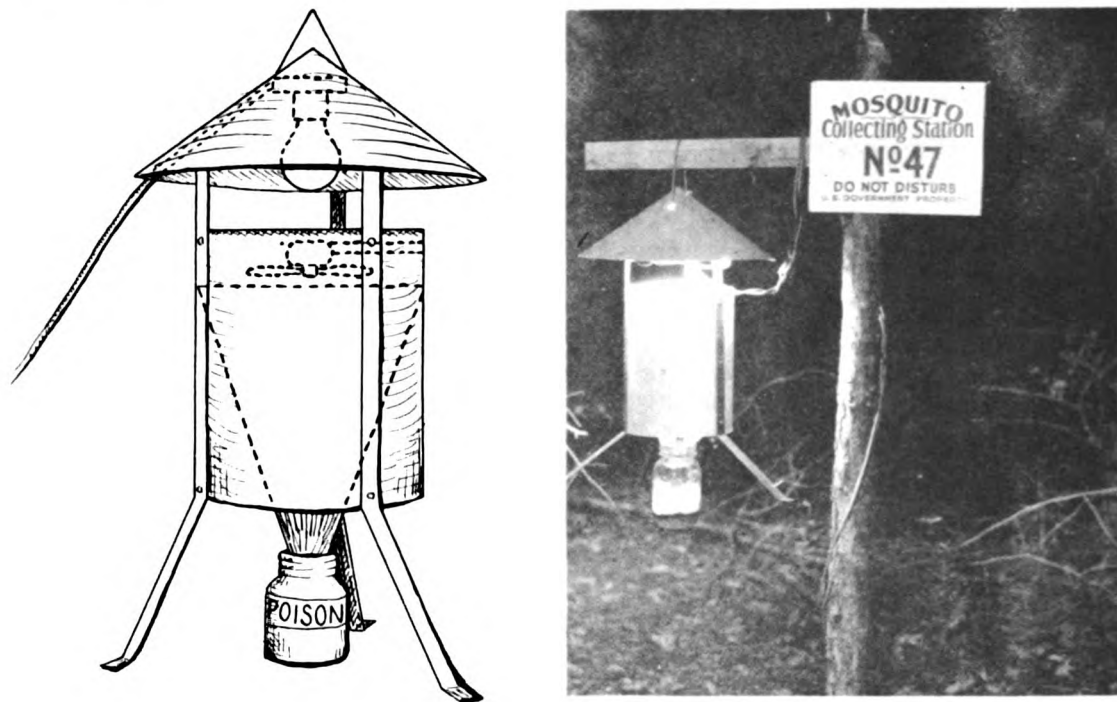
Figure 138.
Light trap. Detail of construction and trap in operation.

Mosquito light traps are usually hung about 6 feet above the ground. This is is out of reach of children and most animals and can be seen by the mosquitoes for a considerable distance. If only one trap is available it may be used at several designated points. A "Poison Gas" sign should be placed in full view to warn of the danger of the calcium cyanide. The insect specimens caught in the trap should be collected each morning and placed in a box labeled with the collecting station number and date.

Biting Collections

These are made by collecting the mosquitoes that alight to feed on one's own body or the body of an associate. If an individual is making the collection, he should sit quietly with trousers rolled up to expose his legs. The mosquitoes are captured with chloroform tube or aspirator as they alight to feed (for day feeders). At night he remains quite for several minutes, then illuminates his legs with a flashlight and collects the mosquitoes. If an associate is used for bait, he should be stripped to the

210

waist. The collection rate is expressed in number of mosquitoes per hour, per station. Since individuals vary in their attractiveness to the insects, it is desirable to utilize the same bait at given stations throughout the survey.

In some areas biology classes may participate in this phase of the survey as a class project. The students are instructed to sit at a given location (usually at home) at a certain time (after dusk), each day and make the collection. Results are submitted to the class and later to the survey personnel. This method is not recommended in areas where serious mosquito-borne diseases are prevalent.

Other Collecting Methods

A few methods have been used for special purposes and for mosquitoes with peculiar habits or adaptations but these have restricted application and are not used extensively. An insect net may be used to sweep grassy areas that harbor mosquitoes. A bobbinet cone may be placed on a revolving boom that rotates in a horizontal plane at about 1 revolotuion per second. A percentage of the mosquitoes flying in the area will be caught in the net. Such a net may be mounted on an automobile and driven about the survey area. Some mosquitoes are attracted to high pitched hums of electric generators and males of certain species are attracted to recordings of the mating hum of the female. Traps have been made to take advantage of this attraction.

Flight Range

In order to establish the area that must be controlled around a protected community or station, it is important to know the normal distance the important vectors or pests can fly. The flight range has been determined and recorded for many species. When this information is not readily available, observations over long periods may give a fairly accurate estimate of the range of a given species. However, this information usually is required for planning the campaign and must be determined during the survey.

Several methods have been utilized for flight range determination. Most methods utilize tagged mosquitoes (radioactive materials, various dyes, fluorescent powders, etc.) released at a given point and collected at specified collection stations. One worker uses a dye on the mosquitoes and sets up white sheets in front of lights at specified distances from the point of release. The sheets are inspected for marks indicating a tagged mosquito had touched it. If mosquitoes can be released at a point where the available blood meals are in one direction only , the task is made simpler.

Mosquito Proofing or Screen Survey

Good mosquito proofing is the first line of defense against mosquitoes and mosquito-borne disease. man can live comfortably and safely in mosquito-infested areas if protected by window and door screens or mosquito nets. On most military

211

installations, mosquito surveillance should include a periodic inspection of screening integrity. Surveys regarding the proper use of bed nets during field maneuvers or in combat areas are required. During World War II, bed net checks were made each night by the mosquito control personnel of many units.

Screening surveys should include inspection of all living quarters, mess halls, theaters, recreation buildings and working areas where personnel work or are congregated after dssk.

Data for each building should include the number of doors and windows without screens, screens in need of repair, screens propped open, screens improperly fitted or hung (swinging inward), and other openings permitting mosquitoes to enter into the building.

Equipment for Collecting Adult Mosquitoes

Equipment for collecting mosquitoes ranges from very simple devices to electrically operated apparatus. A skillful collector may make excellent collections with simple equipment, and most workers devise and make their own.

A very satisfactory collecting tube (a chloroform tube) may be made from any convenient size glass bottle or test tube. A potato tube, about 1 inch by 7 inches, is good. The tube is filled to a depth of 2 inches with small rubber bands or chips and saturated with chloroform (Fig. 203A). A layer of cotton (1/2 inch) is placed on top of the rubber, and one or two tight-fitting disks of cardboard are pressed into place on the cotton. A tight fitting cork is used to seal the tube when not in use. The tube will remain charged for days, even weeks, and can be recharged with chloroform periodically. Tape may be placed around the butt of the tube for protection against breakage.

When using, the cork is removed and the tube is kept closed with the thumb. With a quick but even, sure move, the mouth of the tube is placed over a resting mosquito. Immediately the mosquito will fly or drop into the tube and be overcome by the chloroform fumes. The thumb covers the tube in between captures. Care should be taken not to disturb the mosquitoes resting nearby.

Various types of aspirator tubes have been devised that are very effective collecting tubes. One type is a plastic tube about 1 inch by 7 inches, with an inverted cone in the collecting end and a 3 foot rubber tube at the other end for mouth or large rubber bulb aspiration (Fig. 203D). Fine gauze over or in the rubber tube prevents mosquitoes from being drawn into the mouth. Another type is made from glass tubing, up to 1/2 inch in diameter by about one foot long and fitted with 3 feet of rubber tubing (Fig. 203B). A stabbing motion at a resting mosquito and application of quick suction as the tube reaches within 1 to 1.2 inch of the insect usually will capture it. It is best to stop the tube just before touching the surface where the mosquitoes rest. With a little practice, an inspector can capture one mosquito after another in rapid order. When mosquitoes pack the tube to the extent that aspiration is reduced, they may be blown

into a killing tube, small screen cylinder or collecting box. A focusing flashlight is required for dark areas. If the beam of light is aimed at an angle of about 15° to the surface the insects will be seen easily.

Small pill boxes, labeled with pertinent data, may be used for transporting dead mosquitoes. Thin layers of cotton covered with lens paper will protect the mosquitoes from damage. Live specimens may be transported in small screen cages, bobbinet (even old nylon hose sections) over a collapsible wire frame, or in small boxes fitted with thin rubber containing apertures. Rectangular pill boxes, fitted with a plastic window at one end and two layers of thin rubber with slits bisecting each other at right angles at the other end are ideal mosquito boxes. The mosquitoes are blown from aspirator tubes in through the slits in the rubber sheets. Cigarette smoke, chloroform, ether, etc. blown in through the slits will knock the mosquitoes down or even kill them. The box is not opened until the mosquitoes are knocked out, as seen through the plastic window.

Larval Mosquito Surveys

There are fewer techniques and methods for collecting mosquito larvae than for adults. Since larvae cannot be enticed into a trap, they must be searched for and captured in their natural environment. As the survey progresses and during surveillance, adult mosquito collection data is valuable for indicating areas where the larvae are likely to be found. The various species have decided preferences for certain types of water and almost every aquatic environment is utilized by one or more species. It is important to know the general breeding habits and preferences of the species. Although most mosquitoes like fresh water environments, many can develop in brackish water, and even in pure sea water. Some larvae are primarily surface feeders (Anopheles), while others feed mainly on the bottom. The Aedes in general are found in small artificial containers, tin cans, vases, coconut shells, wooden kegs, automobile tires, bamboo stumps, tree holes, and even crab holes. Many of the genus Culex prefer polluted waters. Anopheles prefer larger bodies of water such as ponds, lakes, swamps, marshes, streams, barrow pits, rice paddies, irrigation ditches, watering troughs, road ruts, etc.

It is not difficult to find the mosquito larvae in small artificial containers and the larvae can be collected easily by pouring the water through a strainer or by the use of a small pipet (wide mouth medicine dropper). It is much more difficult to find and collect larvae in a rice paddy, in vegetation in a pond or lake, or in rapid flowing streams.

213

Equipment and procedures for examining bodies of water for larvae and for collecting them are quite simple. Any small container suitable for dipping without disturbing the surrounding area is adequate. White enamel dippers about 4 inches in diameter and with hollow, open handles are used by most workers (Fig. 139). The larvae are easy to see in a white dipper and the handle may be extended by inserting a wooden or bamboo rod. Some workers use a shallow, white enamel pan for dipping or as a container for examining several dips at once. The pan may be floated on the water surface while the larvae are removed. Several types of special dippers have been designed by various workers, some with screen ports for allowing the water to escape without loss of the larvae, and some designed to measure the volume of water examined.

Figure 139.
Dipping for anopheline larvae

Many water areas may be investigated from the shore or bank while larger bodies may require extensive wading or using a boat. In any case, the inspector should proceed in a manner to prevent disturbing the water. Disturbances, either by surface or shadows, may cause the larvae to dive and remain at the bottom for considerable time. Anopheles larvae are collected by skimming the surface of the water until the dipper is full, being careful not to cause it to overflow. When the larvae are feeding near heavy vegetation, the dipper may be inserted in the water so as to draw or "suck" the water and the larvae into the bowl. Culicine larvae usually dive at the least disturbance and should be dipped with a quick motion. They tend to congregate in the shadow areas of a container. A siphon or long pipet with a large rubber bulb may be used for collecting larvae from tree holes, bamboo stumps and other inaccessible containers where a dipper cannot be used.

214

Routine survey during control operations (surveillance) is required to evaluate the effectiveness of the control and to indicate areas that need special attention. Success of a control program can not be determined by number of gallons of insecticide dispersed or number of feet of drainage ditches constructed or maintained, but the reduction or elimination of the adult mosquito population is significant. During control operations, a significant increase of mosquitoes at an adult collecting station is indicative of inadequate control measures or of breeding areas that have been missed. A more thorough survey of the larvae in that area is in order. If the collecting station is in the periphery of the control zone, the mosquitoes could be invading the area from uncontrolled territory.

The collection of fourth instar larvae or pupae in the larval survey indicates a breakdown in control procedures. Collection of first or second instar larvae where temporary measures, such as larvicides, are being used may not be significant since they could have developed during the period between spraying and survey. Data from the larval survey during temporary control may serve to justify employing permanent control measures.

Site Selection

Information obtained from the preliminary surveys should be most valuable for determining the location of military stations, camps, bivouacs, and in some instances, civilian communities. Frequently the military situation dictates the location of camps with little or no choice. Even when there is a choice, camps or other military installations frequently are established in areas with a high mosquito population. Many times the site for a camp is selected without due forethought of mosquito dangers.

Certainly it is logical to locate installations with susceptible personnel out of the flight range of mosquitoes and the diseases they transmit. If such areas exist in the locale for a proposed installation, the preliminary survey should determine it. The normal flight range for many mosquitoes is approximately one mile but some mosquitoes are capable of flying much greater distances. If a site does not exist out of the range of the mosquitoes, the area most likely to be controlled with the least expenditure of time and funds should be chosen.

Larvae are usually removed from the dippers or pans by means of a wide mouth pipet (medicine dropper), with a screen paddle, or various aspirator devices. They should be placed in small bottles, vials, or other suitable containers, labeled with the larval collecting station number, or other pertinent data, for transportation to the laboratory. The larvae require an air space in the bottle, avoidance of prolonged exposure to direct sun, and careful transportation to prevent jostling.

Evaluation and Utilization of Survey Data

After completion of the survey, either preliminary or basic, the data should be studied and analyzed, together with the parasite or disease survey data, in order to determine the need for control and to make an intelligent decision as to the most efficient and economical control program to be established.

When it has been established that a mosquito-borne disease is prevalent in an area (see page 206) and if an efficient vector (determined by dissection) is present in sufficient numbers that transmission is likely, the need for control is justified. If control of the disease is the only objective, the attack may be directed at only one, rarely more, species of mosquito. Species sanitation is much less costly than control of all mosquitoes. Permanent control measures directed at one vector will also control many other species.

It is difficult to set arbitrary figures for the number of adult mosquitoes collected that indicate a need for control. Other factors such as host preference, biting habits and infectivity must be considered. In some programs, counts ranging from 10 to 20 females per collecting station within a 1/4 mile zone of the protected area indicate lower limits of tolerance. Higher counts indicate a danger.

MOSQUITO CONTROL

General

By the time mosquito control procedures have begun, several important things should have been determined and accomplished; the purpose for which the control program is undertaken, the incidence of disease or annoyance that is to be diminished or eliminated, the kinds of mosquitoes causing the problem, their numbers, their preference for feeding, their breeding habits, and their most vulnerable spots. By this time the methods of control that will accomplish the purpose should be clear.

Types of control have been classified in several ways; there are social, educational, and legal measures that are important adjuncts apart from the direct attack on the mosquitoes. One classification divides the measures as follows:

Naturalistic or Biological Control. Nature strives to maintain a balance and there are many enemies for almost every living thing. The manipulation of natural adversaries of mosquitoes may be employed and encouraged for assisting in the control. Ornamental pools and other small bodies of water may be stocked with predacious fish, principally Gambusia affinis, that feed on mosquito larvae. One mosquito, Toxorhynchites brevipalpus, having plant-feeding adults and mosquito-eating larvae has been introduced into Hawaii for mosquito control purposes. Small floating aquatic plants (duckweed, bladerwart, watershield, euglena) that cover the entire water surface in a dense carpet, may inhibit mosquito production. Some mosquitoes have a preference for dense shade; other prefer open areas. The manipulation of shading vegetation, either to increase the shade on breeding areas or the removal of vegetation to let in sunlight, has been effective in controlling certain mosquitoes. The destruction of adult harborage, such as tall grass and low vegetation near the protected zone, may reduce the adult population in the vicinity.

Mechanical or Engineering Control. Manual or machine operations or the use of physical constructions for restricting, reducing or eliminating mosquito breeding areas are classified as mechanical or engineering control. Such measures include draining of swamps and marshes, filling or grading to prevent collection of water, shore line and stream straightening and improvement, water margin management, flushing of streams, fluctuation of lakes and control of tidal action. The last three are sometimes included in naturalistic control. The use of screens is sometimes considered under mechanical control measures.

Chemical Control. The utilization of toxic chemicals for killing mosquitoes or for repelling them is important in control of mosquitoes, especially in temporary control. Larvicides are chemicals employed for killing the aquatic stages and imagocides are used to kill the adults. Petroleum oils, Paris green, pyrethrum, some of the "wonder" insecticides such as DDT, chlordane, lindane, BHC, etc. have been used extensively.

217

Phases in Control

For many practical purposes control programs are sometimes divided into temporary or permanent control, depending on a number of factors. Each situation must be evaluated in relation to the findings of the survey, the urgency of the situation, and the tenure in the area. Naturalistic, mechanical and chemical control measures are employed and overlap in both classifications. Temporary control methods (especially with chemicals) are considered in detail in the "Manual of Naval Preventive Medicine" (NAVMED P-5010 pp. 9, 10, & 11) and permanent measures (with emphasis on engineering) are presented in detail in "NAVDOCKS TP-Pu-2 Manual."

Temporary Measures

In emergency situations a quick knockout of the mosquitoes capable of transmitting a disease and a prevention of repopulation of the area with like mosquitoes is required. In military and combat situations, the possibility of a short tenure in an area is a limiting factor for establishing permanent control measures. Most mosquito control programs utilize temporary measures extensively, especially in the primary or beginning phases. In most instances it may be practical to utilize permanent measures in civilian communities and in military installations that are permanent or are intended to be used over extended periods of time after the initial or temporary assault on the mosquitoes.

1. <u>Personal Measures</u>. The means by which an individual may protect himself from mosquito bites and the pathogens they may transmit are temporary in the sense that they contribute nothing of permanent value in lessening the mosquito population. Such measures are invaluable when invading uncontrolled areas with a high mosquito population such as may be encountered in combat areas, on fishing, hunting, camping, or exploring trips. Under such conditions personal measures frequently are the only measures of protection. The application of these measures is so vital to military campaigns in malarious areas that "malaria discipline," a term used to describe the ability and readiness of military personnel to utilize malaria control practices, especially personal protective measures, receives high priority in indoctrination and training of troops for duty in such areas.

The most important step in indoctrination of malaria discipline is imparting the importance and gravity of mosquito-borne diseases to personnel and campaigns, and to dispel the idea, prevalent in some "fighting men" of all ranks, "we are here to fight the _____ and to hell with the mosquitoes." Adequate directives and enforcement are required to insure compliance. Malaria control personnel, line and staff, have been used effectively in inspection and reporting of breaches in malaria discipline.

a. <u>Protective Clothing.</u> It soon becomes apparent, even to the unindoctrinated, that proper clothing (fatigues) affords protection from mosquito bites. The value of gloves, boots, leggings and veils in this regard is well known. The officer of the day is responsible for enforcing protective clothing regulations.

218

b. Repellents. A number of chemical compounds have been developed for skin application and clothing impregnation that are highly effective mosquito repellents. Some repellents are effective against certain mosquitoes but ineffective against others. Some contain several repelling chemicals and are therefore more effective for a wider range of species. It is important to indoctrinate personnel to the fact that although the repellent will afford protection from mosquito bites it probably will not be sufficiently effective to keep them out of hearing range. The "sing" may even be louder due to the irritation and excitability of the mosquito caused by the repellent.

A repellent may be the only protection, except clothing, that can be used in advanced positions in combat. The personal size, 2-ounce bottle is convenient to carry and 12 to 15 drops rubbed between the hands and then spread evenly over exposed skin affords protection for hours in the absence of rain or perspiration. Although repellents are safe for skin application they should be kept away from the eyes.

c. Bed Nets. Mosquito nets have protected man from mosquitoes in various tropical areas for many years. Nets have been designed for bed rolls, cots, and hammocks and are effective if used properly. (Fig. 140.) They must be tucked in and closed and the sleeper must refrain from contacting the net during the night. Routine "bed net patrols" are valuable in highly malarious areas for promoting compliance with rules of proper use.

Mended hole — — Net hung inside supports

— Net tucked under all around
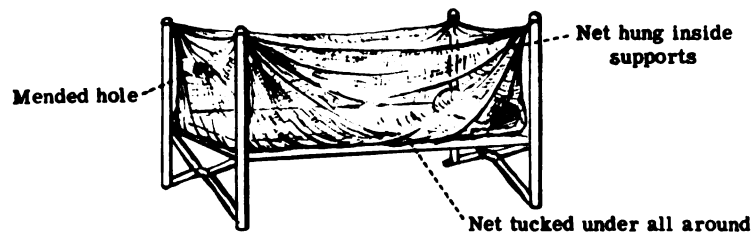
A - THE RIGHT WAY TO HANG YOUR BED NET!

Holes not repaired — Net hung over supports

— Not tucked in
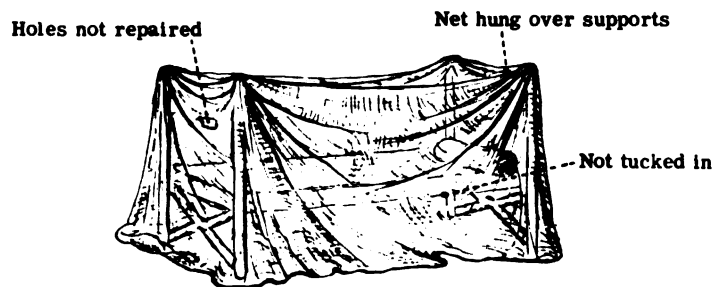
B - THE WRONG WAY TO HANG YOUR BED NET!

Figure 140.
How to hang a bed net.

219

d. Space Sprays. Aerosol bombs containing an insecticide effective for a quick knockdown or kill of mosquitoes are valuable in enclosures and, to a degree, in open areas. Plunger type hand sprayers are useful for discharging a fine misty spray, but are effective only in enclosures. These insecticides usually contain DDT plus pyrethrum or one of the thiocyanates for quick kill. Such sprays have little or no residual effect; therefore they should be used when mosquitoes are evident.

e. Avoidance of Exposure. An occasional exposure to the bites of uninfected mosquitoes may cause little or no harm, but the result from exposure to the bite of one infected mosquito could be drastic. Unfortunately there is no means of determining the infectivity of a mosquito on the wing or while it is feeding. It is wise to avoid exposure to bites of all mosquitoes. This is especially true in civilian communities (native villages) where the mosquitoes are most likely to be infected. Known infected areas should be placed "out of bounds" and regulations should prohibit swimming and bathing in exposed areas after sundown.

f. Medicinal Prophylaxis. During World War II, mepacrine (atabrine) a drug used as a substitute for quinine, was used at a dose of 0.1 gram per day for suppression or prophylaxis for malaria. It was a very effective prophylaxis but not curative. Due to the tremendous amount of research on antimalarials during World War II (probably second only to the research on the atomic bomb) several drugs have been developed that are superior to atabrine and quinine in many respects. They are less toxic, more prophylactic, given in smaller doses, longer intervals between doses, and can curb many vivax and falciparum attacks. The routine administration of chloroquine or primaquine as a prophylactic measure is essential for military personnel in malarious areas.

2. Control of Adult Mosquitoes. The adult mosquitoes present in an area should be the first concern of the mosquito control operations. They are ready and eager for a blood meal, are the vectors of diseases present, and are the progenitors of succeeding generations. If all adult mosquitoes could be killed in a period of a few days the problem of mosquito control would be simplified. This is extremely difficult, if not impossible, even in small or isolated areas. However, a well planned and executed control program utilizing imagocides will present excellent results. This should be conducted in conjunction with attack against the larvae, since it has restricted value when used as the only method of control. This does not mean that it could not be used to advantage as the sole means to control malaria in many areas. In some areas of the world malaria has virtually been eradicated by the use of residual treatment of dwellings.

a. Indoor Control. Attack against mosquitoes indoors is important for protection of the occupants of buildings and for destroying the mosquitoes that have obtained blood meals (requisite for egg production and for transmission of diseases).

(1) Space sprays. Quick kill of the mosquitoes indoors may be obtained by applying liquid insecticides with atomizing type sprayers such as the plunger type

220

hand sprayer ("flit guns"), aerosol bombs, compressed air sprayers (paint sprayers), electric aerosol generator, etc.. The standard Navy space spray contains DDT plus a quick knockdown agent (one of the thiocyanates). The aerosols are much superior to the sprays due to the smaller particle size produced. Aerosols are effective indoors at a rate of 6 seconds of discharge in 1000 cubic feet of space. Such sprays must be used when mosquitoes are in evidence since they have little or no residual effect.

Insecticidal fogs are particularly useful for treatment inside large buildings, in places where furniture and other effects may be damaged by spray droplets of large size, and in difficult or inaccessible places.

(2) Residual Sprays. The most important advance in insect control was achieved with the development of insecticides that retained their killing powers over extended periods of time and were lethal to most insects coming in contact with them. Most surfaces treated with insecticides having residual effects may retain their killing properties for several weeks, even months. Most of the chlorinated hydrocarbons have residual qualities (DDT, lindane, BHC, dieldrin, chlordane and methoxychlor are examples). Unfortunately many insects are capable of developing resistance to many of these powerful insecticides. Indiscriminate use of these insecticides by uninformed personnel not only may tend to accelerate resistance in the insects but also has the danger of poisoning man and animals.

DDT is the most useful chemical for insect control and is particularly effective against mosquitoes. Unless resistance has been demonstrated by personnel in resistance testing it should be used for residual sprays against mosquitoes. Residual spray containing 5.0 per cent DDT in 95 percent odorless kerosene or a 5.0 per cent DDT water emulsion is recommended and authorized. The spray is applied as a wet spray (just short of runoff) to all surfaces where mosquitoes rest. A dosage of one quart for each 250 square feet of surface area is adequate. A 5.0 per cent water solution of water-dispersible powder is more effective on rough absorbent surfaces.

The residual spray is applied with decontamination-type sprayers, 2-3 gallon capacity; the 2-quart hand operated sprayer, or portable power sprayers. The fan-type nozzle is preferred and should be held 15 to 18 inches from the surface being treated.

b. Outdoor Control. It is more difficult to attack and kill adult mosquitoes in open areas than inside of buildings. Meteorological conditions, vegetation, buildings and other interfering structures play an important role in the success or failure of outdoor spraying, fogging, or misting operations.

Space Treatment. Several space-spraying machines have been developed for applying smokes, fogs or mists that kill mosquitoes out of doors. The insecticidal material is broken up into minute particles by thermal or mechanical generators or by the action of high-velocity streams of air or gas. The spray particles in fogs or mists come in contact with and adhere to mosquitoes where they are absorbed through the

221

body wall causing death. Usually the treatment is more effective at night than during the day. Most mosquitoes are active at night, the air and ground temperatures are more equal which lessens the action of inversion currents, and usually the air is less turbulent. It is important that the operator of such equipment be well trained in their use. He must have an understanding of the adult habitat, flight patterns, resting habits, killing action of fogs, inversion currents, fog drifts, as well as a thorough knowledge of his equipment. The adjustment of the equipment for production of a fog with the proper particle size without heat breakdown of the insecticide is essential to good results. The equipment must be maneuvered so as to treat a swath from 100 to 200 feet down wind. A light breeze may help disperse the fog to a greater distance but wind velocities greater than 7 miles per hour render the treatment ineffective.

A formulation of 8 to 10 per cent DDT, applied at a rate of 8 gallons per linear mile, is usually satisfactory. The vehicle in which the equipment is mounted should proceed at a speed of 5 miles per hour or less.

Frequently fogging operations serve only as a morale builder, but routine application, regardless of need, is wasteful. Fogs or mists do not persist in an open area for long period; therefore, in areas of high densities of adults or where an influx of mosquitoes from other areas is continuous, repetitive treatment is required. The interval of treatment must be governed by local conditions.

Aerial Sprays. Aerial insecticidal spraying or dusting has limited application for control of adult mosquitoes in that usually only the mosquitoes that are flying or are in the open are killed. Aerial dispersal is conducted during periods of the day when mosquitoes are inactive. Although a fair degree of adult kill may result, many factors must be considered to justify such applications.

Residual Sprays. There are relatively few situations in outside areas where residual spraying might be used to advantage in adult control. Dense shrubbery, vines or other plants that harbor mosquitoes, the leeward side of buildings where mosquitoes collect, and known diurnal resting places not used as collecting stations, may be treated with residual sprays. Hibernation places are sometimes treated to control the adults overwintering there. The action of the elements in washing residual material away, and difficulties in applying the spray to the best advantage (under leaves and other objects where mosquitoes rest) limit effectiveness. When residual applications are justified, an aqueous emulsion or suspension of 5.0 per cent DDT is recommended, and it should be applied as a wet spray on leeward sides, recessed angles of buildings and to all vegetation in an area of 100 feet around the buildings.

3. Control of Larvae. Successful mosquito control programs have been conducted by using larvicides alone. Larviciding is the term used to denote the killing of mosqui- larvae by the use of toxic chemicals. Petroleum oils were first used to kill mosquito larvae even before their role in disease transmission was known. Later Paris green was used in control of Anopheles. During World War II powerful insecticides were de- veloped that were very effective even in small quantities, and their killing powers

were long lasting. Petroleum oils have not been entirely replaced by the newer insec-
ticides for larval control in that the oil is the usual solvent or vehicle for them. In
this case the effectiveness of the oils has been greatly increased. Petroleum oils and
Paris green as larvicides are discussed because there may be times and conditions
where they may be indicated.

Figure 141.
A control team larviciding a lagoon in a combat area.

Larviciding should begin in the spring or as soon as larvae are detected by survey
teams. Usually all breeding areas should be treated at weekly intervals. (Fig. 141).

Petroleum Oils. Unlike fish and many aquatic animals, mosquito larvae obtain
their oxygen from the air through tracheae or "breathing tubes," and not from the
water by gills. With the exception of one genus (Mansonia), mosquitoes obtain their
air through the surface of the water. When oil is spread over the surface of the water
it enters and fills the breathing apparatus. The killing action is twofold in that suffo-
cation and poisoning result. The most satisfactory oils are those of medium viscosity,
volatility, and boiling range. Heavy oils, though toxic, do not spread well and light
oils are too volatile. Diesel oil (No. 2) and unrefined Kerosene have been most satis-
factory. They fulfill the most important requirements or specifications: (1) high tox-
icity to larvae and pupae, (2) good spreading qualities on water surface, (3) fast penetra-
tion of tracheal system, (4) stability of film, (5) non toxic to fish, fowl or mammal when
used properly, and (6) economical.

Paris green. Anopheles larvae are surface feeders (see section II) while most
other mosquito larvae feed primarily on the bottom. Paris green, an arsenical
$(Cu(C_2H_3O_2)_2 \quad 3Cu(AsO_2)_2$, has been used extensively as a tool for species control in
malaria control projects. Since the action of the mouth brushes of Anopheles larvae

223

sweeps floating material into their alimentary tracts they are subject to poisons that float. Species that feed on the bottom may not be affected. First to fourth instar larvae can ingest particles from 30 to 100 microns in size.

Approximately one pound of Paris green is sufficient to treat one acre of water surface. Of course it is difficult to distribute one pound of powder over an acre of water evenly, so a diluent is required. Almost any kind of dust that will float and can pass a sieve of at least 30 meshes per linear inch is satisfactory. Road dust has been used frequently. Usually a one to two per cent mixture is sufficient, but higher percentages are required for power and aerial applications. Applications at weekly intervals during the breeding season are required for most areas. A rotary blower duster is usually used to disperse the mixture.

Paris green may also be dispersed as an emulsion: 400 ml. of kerosene, 200 ml. of Paris green mixed with 1 gm. of egg albumen is used to prepare the stock solution; 25 ml. of the stock material are mixed thoroughly with 5 liters of water and dispersed with the same type sprayers as are used for oil larvicides.

DDT. The larvicide of choice for control of most mosquito larvae is Dichloro-Diphenyl-trichloroethane, $(C_{14}H_9Cl_5)$ or DDT. It was developed during World War II and has practically replaced oils, Paris green, and other chemicals as larvicides. Although residual sprays are being used primarily as imagocides for control of adult mosquitoes in malaria control projects they still have a decided use as larvicides in total mosquito control programs. DDT does not deteriorate or evaporate rapidly and its prolonged residual effectiveness is a principal advantage over most insecticides. One advantage is its effectiveness in many very small doses. It has been estimated that a 1 to 100,000,000 dilution is lethal to mosquito larvae in 24 hours. One disadvantage is that some mosquitoes have developed a resistance to it and there are indications that this trend may increase.

DDT in its purified form is a white crystalline substance with a melting point of $108^{\circ}C$ to $109^{\circ}C$. It is soluble in most organic solvents but relatively insoluble in water. Its physical properties permit it to be dispersed in oil solution, emulsions, water-dispersible powders, diluted dusts, aerosols, and fogs.

Ground larviciding. DDT is extremely toxic to mosquito larvae and very small amounts will give good control if properly dispersed. As little as 0.1 to 0.2 pounds in 1 to 2 quarts respectively of a 5 per cent solution of oil per acre of water surface usually is sufficient for control, but it is difficult to get an even distribution of such a small amount. In areas where beneficial wildlife is not a factor to consider, 3 pounds per acre may be used for a long residual effect.

DDT dissolves readily in diesel oil No. 2 and kerosene. It requires about 24 hours to dissolve an amount to produce a 5.0 per cent solution. Two pounds of DDT in five gallons of oil will provide approximately a 5.0 per cent solution. When 1/2 of 1 per cent of a spreading agent such as Triton B 1956 is used to increase the spreading coefficient,

0.1 pounds per gallon of oil is a satisfactory mist larvicide. This is applied at a rate of 1 gallon per acre. This may be used effectively in ground-operated equipment.

There are occasions where oil based insecticides are difficult to use or where they are not indicated. The use of dusts may be indicated where crop damage is likely or where vegetation is too dense for penetration by sprays. Concentrated technical grade DDT powder is too coarse to be applied as a powder, therefore it must be mixed with pyrophyllite or talc, and ground in special equipment. Only the 10 per cent DDT powder (pyrophyllite, etc.) would be used. It is dispersed at a minimal rate of 1 pound per acre with rotary blowers or power blowers.

Aerial Larviciding. Aerial dispersal from aircraft provides for coverage of large areas in a minimum of time. There are so many limitations to this means of larvicide dispersal that it is recommended only for very unusual circumstances such as in wartime in foreign areas where mosquito-borne diseases may affect the taking and holding of advance positions. All aerial insecticide dispersal requires prior approval from the Chief of Naval Operations.

When recommended and approved, aerial larviciding requires the utmost coordination between the pilot and the entomologist or qualified technicians. DDT, 20.0 per cent airplane spray should be applied as a fine spray at rates from 0.1 to 0.3 pounds per acre. The spraying should be done during the morning or evening calm.

Resistance. Many insects have demonstrated a marked resistance to DDT and many chlorinated hydrocarbons. There are reports to indicate that mosquitoes develop resistance but as yet not to the extent that occurs in many other insects. Where resistance to DDT has been demonstrated by technicians qualified in resistance testing, BHC or dieldrin may be used. Application rates should be at 0.1 pound of active ingredient per acre for draining areas and 1.0 pound per acre for residual effect. Malathion may be used at the rate of 0.4 pound per acre if general resistance to the chlorinated hydrocarbons has been shown.

Control in water containers. All water holding containers such as tires, cans, broken bottles and boxes should be disposed of if possible. Many items in salvage dumps, vehicle storage and supply dumps hold water and breed mosquitoes. Items that cannot be eliminated or stored so as not to hold water should be larvicided periodically. Fire barrels may be treated by adding 1 tablespoonful of 25.0 per cent DDT emulsion concentrate and mixing. Fish ponds and ornamental pools should be treated with a fine mist of kerosene or diesel oil.

The salt content of water may be increased or decreased beyond the limits of tolerance of certain species of mosquitoes. Such a chemical measure is not practical under ordinary circumstances but where natural environment is such that sea water can be introduced into fresh water breeding areas through tide gates or flumes, control may be obtained. Some species (Aedes togoi, A. sollicitans, A. taeniorhynchus, Anopheles farauti) have a tolerance for salt and would be little affected by changes.

4. <u>Dispersal Equipment</u>. The equipment for dispersing insecticides may be quite simple or may be elaborate, power-driven mechanisms capable of delivering from 40 to 50 gallons of spray per minute. Many types of simple equipment have been devised and almost all workers invent some special gadgets of their own for a particular purpose. Some insecticides may be poured from any convenient container such as tin cans, garden sprinklers, or hypodermic syringes. Larvicides in the form of small pellets or capsules containing about 25 per cent DDT concentrate may be cast into tanks, small pools, or shell holes. A variety of continuous or automatic equipment has been used; drip cans, submerged bubblers, oil bags, and current powered dust dispersers. Although they had a place in may programs utilizing oils or Paris green, they have little or no value in ordinary circumstances for DDT dispersal. In general, dispersal equipment is divided into two main categories: sprayers and dusters. These are subdivided into manual or power-driven, and ground or aerial equipment.

a. <u>Spraying equipment</u>. There is equipment available for dispersing sprays from large volume and particle size to small volume and minute particle size including stream or jet, wet, fine, atomized, mists, aerosols, fogs, and smokes. There are no generally accepted differences to define the last four and usually they are referred to as "fogs." There are numerous commercial models of each type but only standard, recommended items are included in this discussion. The standard equipment is excellent for most purposes but as with all equipment, must be kept in good operating condition. With the newer insecticides, it is essential that hoses be of oil resistant material, that connections be leak proof, and that valves and openings be such that operators are not exposed to the insecticides. Open-top knapsack sprayers should never be used with these insecticides.

(1) The decontamination type sprayer (Fig. 142), either 2 or 3 gallon size, operates on compressed air at a pressure of 30 to 50 pounds per square inch. This is the most commonly used manual portable sprayer and is suitable for larvicides when equipped with the fine-spray nozzle or for residual applications with a fan-spray nozzle. In larviciding, one man may cover from 2 to 5 acres per day, depending on terrain and shore line vegetation. Usually two tanks full of DDT larvaciding solution is the usual requirement. for one day per man.

(2) The 3-quart sprayer or plunger type (Fig. 143) is a useful sprayer when equipped with adjustable or interchangeable nozzles. When the nozzle is set to deliver an atomizing spray it is useful for space sprays in buildings or for larviciding work.

Figure 142.
Cylindrical Insecticide Sprayer,
Two-Gallon Capacity

226

The coarse spray has limited use in indoor residual applications but has little or no value for normal exterior residual work.

     (3) **Power sprayers of many types** are used extensively in mosquito control projects. Two sprayers are available from standard stock in the Navy. Both are liquid insecticidal sprayers, gasoline-driven. One has a 50-gallon tank capacity, skid mounted or mounted on many types of vehicles. The other type has no tank and is designed for mounting on an oil drum. These sprayers may be used in the same way as the decon-

tamination type sprayers, and it is a matter of individual judgement whether or not they are more advantageous to use since they are more difficult to maneuver in relatively inaccessible larval breeding environments. They may be mouned in boats for treating large water areas having indigent vegetation. They are also quite useful for residual application in large buildings.

     (4) **Obsolete screening smoke generators** have been converted to insecticide dispersal equipment that combines residual sprayer, mist applicator and power duster. Instructions and plans are usually required for conversion of this equipment. This converted equipment is renamed MIDA*.

     (5) **Mist blowers** may be used for larvaciding or for outdoor residual applications. Liquid insecticide is introduced into a blast of air which breaks it up into fine-mist particles and carries it along in the air stream. A small volume of concentrated insecticide may be dispersed effectively for long distances depending on terrain, vegetation, and air currents. The particle size is smaller than can be produced by ordinary sprayers but larger than true aerosols or fogs. The initial blast of air may propel the mist in an effective range equal to and sometimes greater than fog generators.

     (6) **Gas-propelled aerosol bombs** of two types are effective for indoor space-spraying: the refillable, high pressure bomb and the nonrefillable, low pressure (beer-can) type. These bombs usually contain DDT plus a quick knockdown agent (pyrethrum or one of the thiocyanates) and are charged with freon as the propellent.

     (7) **Thermal-generated fogs** are useful for outside space treatment for adult mosquitoes under favorable meteorological conditions. They have limited use for inside space treatments in large buildings. Commercial equipment, designed especially for producing insecticidal fogs are superior to converted screening smoke generators or make-shift exhaust generators. The commercial models permit a wide selection of particle sizes, have a large output capacity, and have many safety features. Military

*Not a commercial product

227

specifications are available for recommended fog applicators.

The fog generator is suitable for mounting on a jeep (Fig. 144) or trailer and re-
quires only a driver and an operator. Both individuals should be thoroughly trained
and certified in accordance with existing
directives.

Mechanically generated aerosols are
produced without the use of heat or gas pro-
pellants. The particle sizes are slightly
larger than the fogs or smokes but are use-
ful in the same environments as bombs or
fogs, depending on size and output of the
equipment. The small hand operated
models, portable electric generators,
and gasoline-driven models are used.
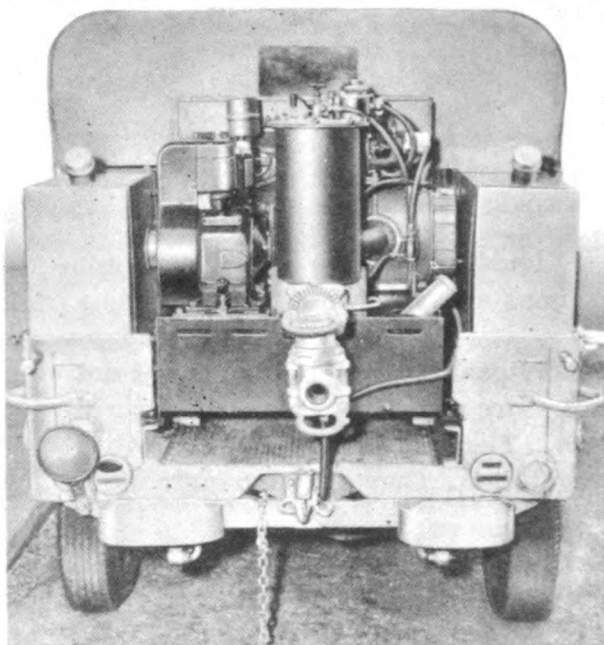
Figure 144.
Fog machine mounted on jeep

b. Dusting Equipment. Equipment
for dispersing insecticidal powders is not as
widely used as spraying or fogging equip-
ment. Dusts have limited aplication in mos-
quito control programs, especially military,
due to difficulties in obtaining suitable dilu-
ents in the field. Dust diluents are bulky and
field mixing is difficult. A small hand duster
plunger type, has limited value even in
small water areas. The rotary-blower
hand duster (Fig. 145) with a capacity of
5 to 10 pounds, is versatile for areas where
dusts are indicated. The equipment is car-
ried in front of the operator, suspended by
shoulder straps.
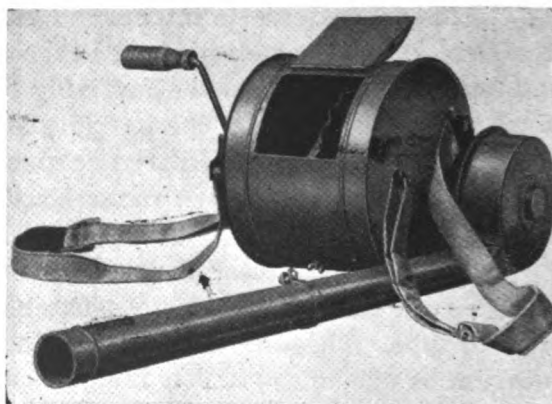
Figure 145.
Rotary hand duster

c. Aerial Dispersal. Various types of military aircraft have been adapted for
dispersing insecticides; fighter-bomber-attack type, C-47, liaison or trainer. and
the helicopter. The dispersal is influenced by the type of aircraft used due mainly to
the speed, handling characteristics, and air turbulence pattern of the aircraft. Sev-
eral types of discharge equipment are used in aerial dispersal of insecticides:

228

pressure-fed nozzle system in which the spray nozzles are mounted on a boom beneath the wing and are pressure-fed from tanks inside the plane; breaker-bar system where the insecticide is discharged against a beveled bar which shatters or atomizes the liquid; venturi-type units, mounted on droppable fuel tanks (Fig. 146), in which the insecticide is introduced into the throat of a venturi where the high velocity of air atomizes the liquid; and straight emission pipe where the liquid is gravity-fed into a pipe opening below the slipstream.
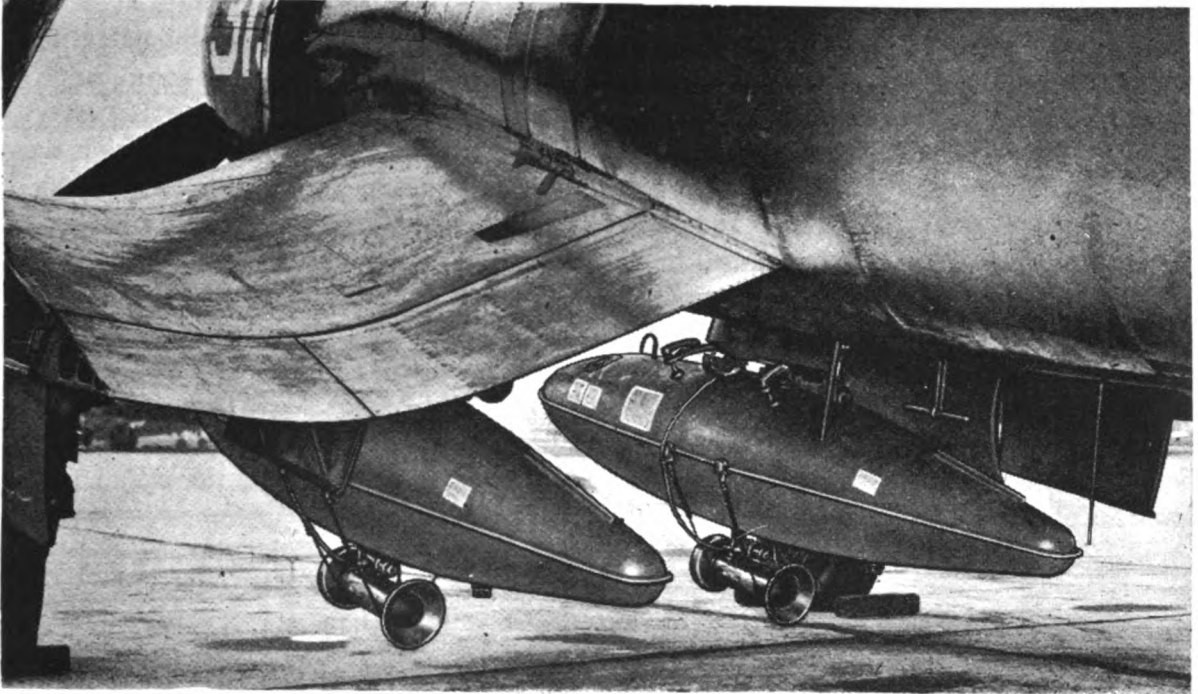
Figure 146.
Spray gear on airplane

Semipermanent Measures.

There are a few mosquito control practices and measures that may be used to advantage in several phases of control. They cannot be classified under chemical control and since they do not materially reduce the mosquito population they are not included under permanent control measures. Examples of these measures are: mosquito-proof construction, screening, and elimination of adult harborage and hibernating environments.

a. **Mosquito-Proof Construction.** In constructing new houses, barracks, and other buildings to be used as quarters, messing facilities, and recreational activities, care should be taken to eliminate features that will be difficult to mosquito-proof. Tight sealed construction is required. In old buildings all cracks, knotholes, flues, vents and other openings (around drains, water and electrical conduits) should be closed or caulked to provide mosquito-proof integrity.

b. **Screening.** Insect screens are the first line of defense against many flying insects and are one of the most important measures for protecting man from mosqui-

229

toes. In many areas that have no control program they serve as the only defense against mosquitoes. They are useful in the temporary control phase, although they have no function in chemical control except as an ideal surface for residual treatment. In spite of the important role they play, screens are probably the most abused of all mosquito control measures. To be effective, screens must be installed on all doors and windows, should be kept in a good state of repair, and should be kept closed.

The most serviceable screens are made of non-corrosive metals or plastic and should have apertures no larger than 0.0476 inches in diameter (18 by 18 mesh). The frames should be sturdy and fitted to the door or window snugly. <u>Screen doors always should open outward and be self-closing</u>. In-swinging screen doors act as ingress valves and personnel entering such doors sweep the mosquitoes resting on the doors into the building. Navy buildings are to be constructed in compliance with National Fire Protection Code which requires that all exit doors, including screen, open outward. See Fig. 147 for details of screen construction. In areas where disease transmission is high, two doors with a screened vestibule between are desirable. Doors should not be placed on leeward sides of buildings or in recessed angles if it can be avoided since mosquitoes tend to collect there. Window screens should be made to cover the entire window area, since sectional or half-screens are difficult to be kept mosquito-proof. In malarious areas, military personnel may be hospitalized with the disease. It is especially important that they be protected from mosquitoes that might become infected.
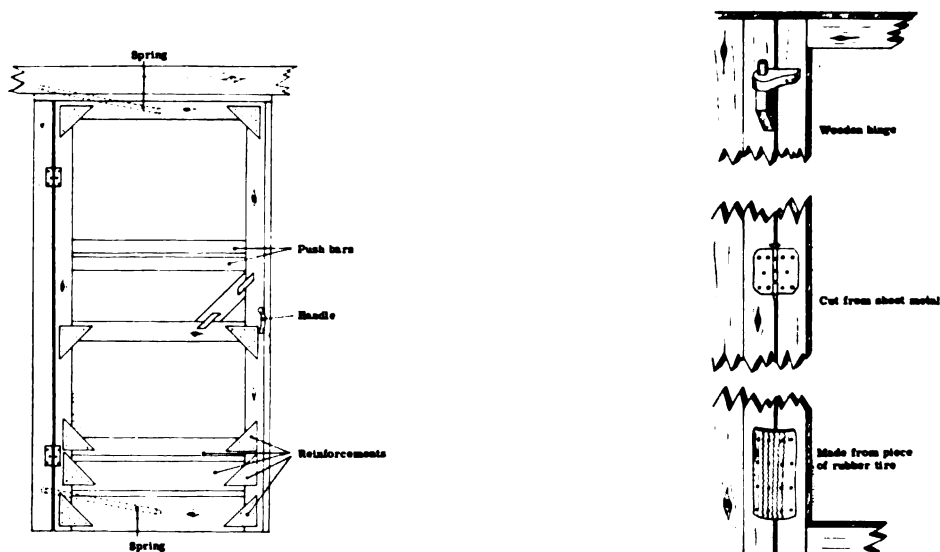
<u>Figure 147</u>.

Properly constructed screen door   Improvised hinges for screen door

c. <u>Destruction of harborage</u>. If dense vegetation surrounds the area to be protected, mosquitoes will sometimes rest there during the day. Removal of the underbrush and tall grass in the area denies them this protection. Brush piles in the area of control should be destroyed for the same reason.

Permanent Control

Permanent control is in essence mechanical or engineering control in that these physical manipulations tend to destroy or alter the environment or conditions for production and development of mosquitoes.

Mosquito larvae require water in which to develop. The volume of water is not as important for development as surface area and surface environment. If all water in an area could be removed, control would be established. Steps for reducing water areas or altering the characteristics of water margins and surfaces to make them undesirable to mosquitoes are mechanical in nature.

After parasitologists, entomologists, and malariologists (if malaria is the problem) have completed their basic survey, the engineer begins his study if permanent control is to be established. The engineer and entomologist must work together to set priorities on the work to be performed and to determine which engineering measures are most suitable for eliminating the various species. The engineer should be guided by information obtained with regard to cycles, habits, habitats, preferences and requirements of the individual species. Control methods must be suited to the species of mosquitoes involved. Drainage ditches or land fills are, as a rule, of little or no value against Aedes aegypti or Culex pipiens. Continuing larvicidal programs are wasteful when used against species that produce only one brood per year. Man can produce more extensive and suitable breeding grounds than he eliminates if his knowledge of the species involved is not adequate.

Mechanical control of aquatic stages includes drainage or ditching, filling, pumping, and stream or pond shore clearing or maintenance. On small projects, or in areas where low cost labor is available, hand constructed ditches, stream clearing and underbrush removal may be preferred. In war time in foreign or occupied areas, native labor may be utilized to advantage (Fig. 148). Where large ditches (four feet or more in depth) are required, dynamite or heavy earth-moving mechanical equipment such as draglines, road grader, or back hoe may be more practical for savings in time and money.

Figure 148.
Using Native labor

231

Close liaison and cooperation is required between the mosquito control activity and the public works departments and engineering or construction activities. Frequently, new constructions, buildings, roads, and golf courses are established that could be valuable assets to mosquito control if general larval control principles are known and utilized.

(1) <u>Drainage</u>. Mosquito control has as it's purpose the removal of surface water with sufficient rapidity and completeness to prevent the maturation of the aquatic stages of mosquitoes. Such drainage systems must conform to higher standards of engineering than are required for agricultural, highway, or storm systems. In areas where mosquito control is required, all types of drainage should always conform to mosquito control standards insofar as completeness of drainage is concerned. Frequently roadside ditches, storm drains and irrigation ditches are constructed for carrying large volumes of water and little regard is given to residual water. Improperly constructed drainage systems for mosquito control sometimes create more ideal environments for mosquito larvae than they eliminate. Small pools or puddles of residual water in drainage ditches or those that are created by the equipment used for constructing the ditches afford good breeding places for many species of mosquitoes. Borrow pits frequently are prolific breeding areas. In malarious areas, such constructions may result in "man-made" malaria. Mosquito control drainage usually improves the agricultural or commercial merits of the land to a degree that independently would justify the drainage. Drainage to control mosquitoes may be open ditches, subsoil drains, verticle drains, pumps, tide gates, flumes, or other constructions. Consideration must be given to terrain, soil types, gradient, breeding area, maintenance, and cost in choosing the type of drains.

(2) <u>Open ditches</u> are the most commonly used drains for mosquito control programs. They may be of many types from simple dirt ditches to elaborate concrete systems, depending on location, gradient, permanency of project, and available funds. They are usually the quickest and cheapest to construct but require frequent inspection and maintenance. The ideal mosquito control ditch should remove water rapidly enough to prevent mosquito development, both in the area drained and in the ditch itself; should carry normal and peak volumes of water without scouring (erosion) or other damage; and should have flow characteristics that will prevent formation of silt deposits in the ditch bottom. The ideal ditch is not always realized but should be approched as closely as practical considerations will permit.

<u>Laying-out</u> a good ditch and a drainage system requires a careful inspection of the area and good judgement in matters of drains. To drain an area by means of ditches, it is common practice to lay out a system composed of one or more main (primary) ditches to conduct the water from the breeding area (swamp, marsh, etc.) to a suitable outfall, such as a bay or stream (Fig. 149). Each main ditch may have one or several lateral (secondary) ditches to collect water that does not drain readily into the main ditch. To reduce maintenance the number of outfalls should be kept at a minimum. Where practical, two or more main ditches may be brought to the same outfall. Occasionally, where there is no suitable outfall near the area, ditches may be

232

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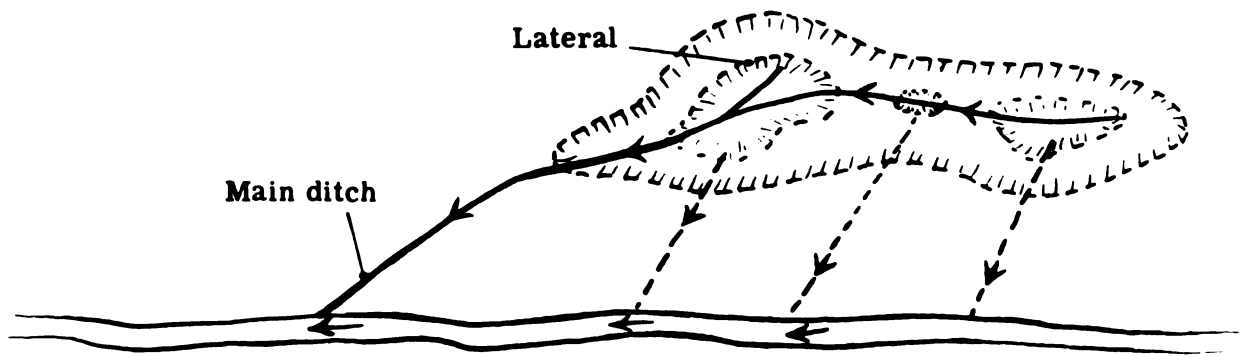
Figure 149.
Ditch systems. Solid line correct. Dotted line incorrect -- too many outfalls

used to carry water to a low point in the adjacent terrain where it can be treated
more effectively. The usual procedure in laying out a drainage system is as follows:

      1. Determine the general locations of all the natural drainage systems by an
inspection of the area. Use the maps that are available and if none is available one
should be prepared before extensive ditching is undertaken. (See Surveying and Map-
ping, page 253.)

      2. Make preliminary survey of the proposed ditch lines to determine the
comparative elevations of outfalls, the area to be drained, and any intermediate high
or low points. Frequently the terrain is such that the best locations for the main
ditches are evident without a preliminary survey.

      3. Determine the final locations of the main ditches on the basis of the pre-
liminary survey. Then set up stakes to mark the center line and make a profile sur-
vey from which a profile of the ground surface may be plotted. The depth and grade
of the ditch are determined from the profile. Depth should be kept within the practical
limits of the means of excavation (hand labor or machine). Where available fall ap-
proaches zero, suitable drainage can sometimes still be effected by depending upon
displacement to move the water along the ditch. Displacement ditches are frequently
used in salt marsh drainage, where tidal fluctuation and surface-feeding fishes in-
hibit mosquito breeding.

      The lines of main outlet ditches should be as straight as possible to prevent
erosion and to shorten the ultimate length of the system (Fig. 150). Where high ground
or other topographic features intervene, a more indirect route following natural drain-
age would be less expensive. Changes in direction should be minimized and gentle
curves substituted for abrupt angles.

233
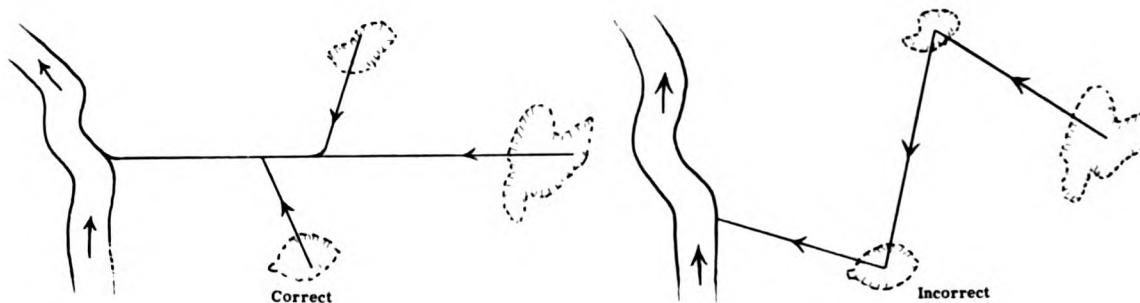
Figure 150.
Ditch alignment

The size and shape of the
cross section and the grade primarily
govern the efficiency of a drainage sys-
tem. The area of the cross section
should be great enough so that water
will not overflow the banks at periods
of peak flow, and the shape should be
such that a minimum of water will re-
main in the least area of the ditch when
flow ceases. The bottoms of the ditches
should be U-shaped and not V-shaped.
In large ditches it is usually wise to dig
a small U-shaped ditch in the center to
convey residual water (Fig. 151). Cor-
rect and poor ditch constructions are
illustrated in Fig. 152.

Figure 151.
The small U-shaped ditch in center of large
ditch
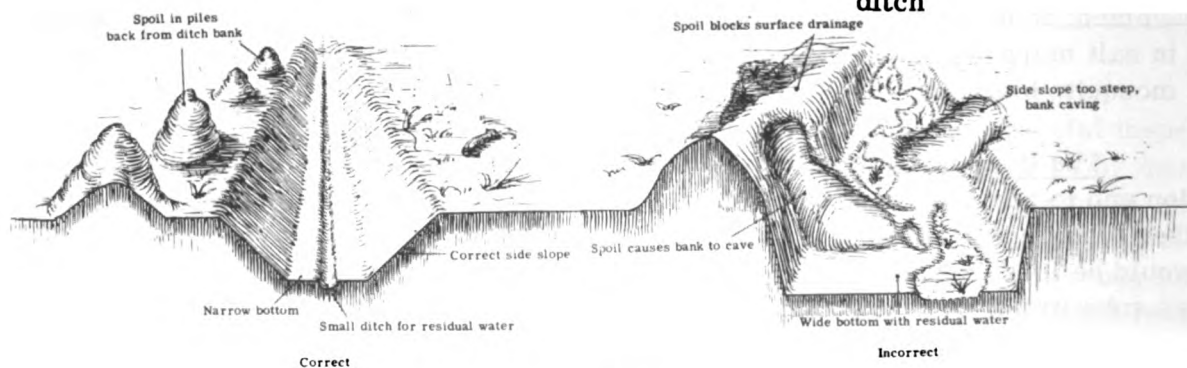
Figure 152.
Cross section of ditches

234

The depth of mosquito control drainage ditches is dependent on the elevation of the area to be drained and of the outfall. The bottom of the ditch must be 6 inches lower than the bottom of pool, marsh, etc. to be drained. Wide, shallow ditches may be constructed cheaply by the use of a road grader or bulldozer. Draglines, back hoes or pan ditches are needed if the depth of the ditch is to be more than 4 or 5 feet.

The grade of a drainage ditch should be just enough to give cleansing velocity, but not enough to erode the banks. If the slope is too flat, silt will be deposited, water will be impounded behind it, and aquatic vegetation will flourish. A grade of 0.2 per cent (0.2-foot drop per 100 feet) is usually best for mosquito control. The slope should not be less than 0.05 per cent or more than 0.5 per cent. When steeper grades are encountered, it is necessary to construct steps of concrete or wood (Fig. 153) or install spillways (concrete, rocks, etc.) to decrease the velocity of the water. A gradual slope down the side of an elevation may be more practical than using the more direct route.

The selection of a grade depends on several factors, most important of which are the length of the ditch and the available difference in elevation between the head and outfall. For example, if a swamp is to be drained into a stream 1,000 feet distant and the difference in elevation between the swamp and the stream is 1 foot, the maximum grade that can be obtained will be 1 per cent. Since the human eye is not reliable as a surveying instrument, some kind of level must be used to establish the grade (see page   ). A uniform grade should be used throughout the length of the ditch since changes in grade increase erosion or silt formation.

The side slope of a ditch should be correlated with the character of the soil. If the sides are too steep the banks will cave in; if too flat, excessive excavation is required in construction. The slope of a ditch may vary from 1/2: 1(1/2 ft. horizontal to 1 ft. vertical) slope in stiff clay to as much as 4:1 in sandy soil. In average soil the sides of a dirt drain should not be steeper than 1:1 (45 degree angle). In such soil a ditch that is 4 ft. deep and 1 ft. wide at the bottom should be 9 ft. wide at the top (each bank is sloped back 1 ft. for each foot of depth). Figure 153 shows the method of determining the slope of a bank.
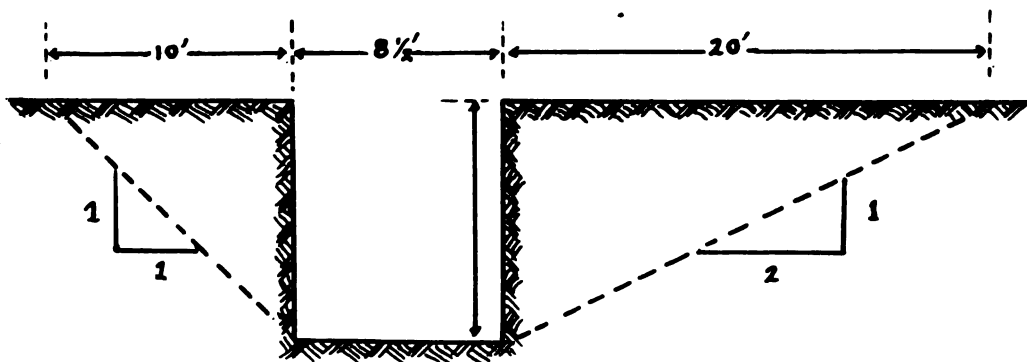
Figure 153
Method of determining slope of ditch bank
235

The spoil bank (excavated dirt) should be so disposed that natural drainage into a ditch will not be blocked (Fig. 154). If at all possible the spoil should be used for filling low areas such as the channel of an old stream. If it is not needed for filling it should not be placed in a continuous embankment.

Figure 154.
Location of spoil bank and berm

The berm is the area between the ditch and the spoilbank and it should be wide enough to prevent the spoil from washing into the ditch and to prevent the weight of the spoil from caving the banks (Fig. 154). For large ditches the berm should be at least 6 to 8 ft. wide and for hand ditches at least 3 ft. wide. A good berm provides a path or road for maintenance work or for larviciding operations when indicated.

(3) Interceptor and lateral ditches. Ditches are sometimes dug around the outer edges of swamps, usually at the foot of the slope from the high ground, to intercept subsurface seepage water. To determine the depth to which the ditch must be dug to intercept the subsurface flow, several test holes should be sunk to the water table around the perimeter of the swamp. See figure 155.
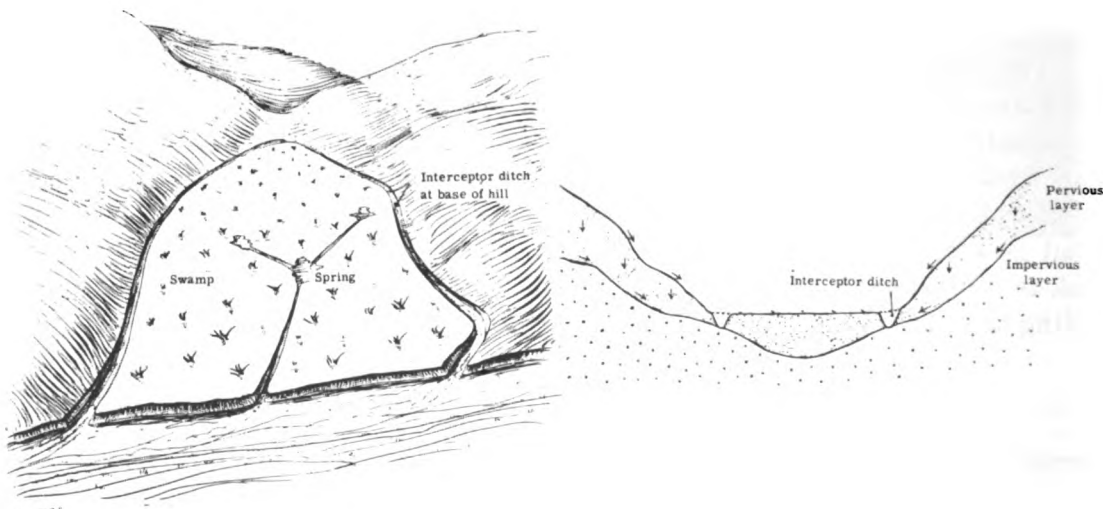
Figure 155.
Interceptor ditches. Perspective, cross section

236

Laterals are laid out in the same manner as main ditches. The number of laterals should be kept to a reasonable minimum at the outset, for small breeding spots close to the ditch system may later dry out by percolation of the water into the ditches.

Ditches should be brought together at an angle of about 30 degrees with the direction of flow (Fig. 156). The ridge formed at the apex of a lesser angle is likely to cave. Where the angle is very much larger, the smaller ditch may be blocked by silt deposited by back water from the larger ditch, and a strong flow of water in the smaller one may erode the opposite bank of the larger. Three-way ditch connections should be avoided because of the excess bottom width at such unions. It is desirable to have laterals enter above the normal level of the main ditch. This will prevent water in the larger ditch from backing into the lateral and depositing silt or forming a quiet pool in which larvae will breed. A difference of a few inches or a foot should be sufficient. The fall into the main ditch should not be vertical but distributed over a distance of perhaps 10 feet on the lower end of the lateral (Fig. 157).

Correct
Intersections at proper angle, converging flow to main ditch, no multiple connections.

Incorrect
1. Lateral entering at incorrect angle
2. Diverging flow
3. Multiple connection
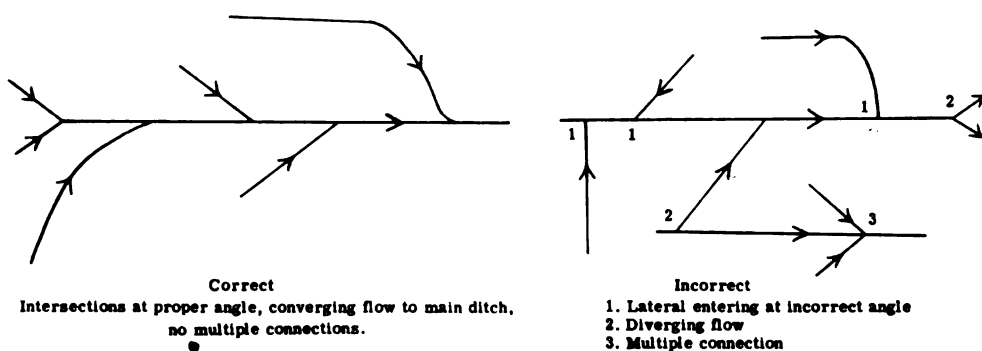
Figure 156.
Location of lateral ditches

Normal water level

0.5'

10

Bottom of lateral ditch
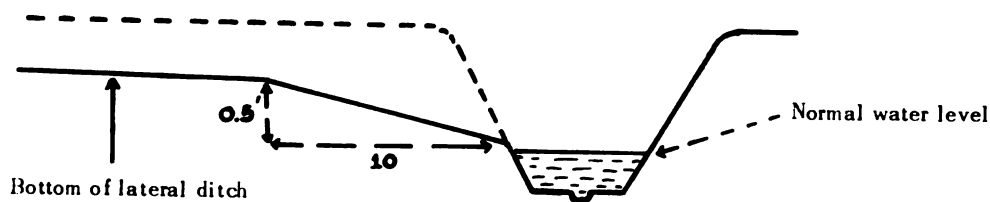
Figure 157.
Entrance of lateral into a main ditch above normal water level

237

Subsurface drains are used where it is necessary for the ground surface to remain unbroken by ditches; where the earth is so unstable that open ditches cannot be maintained; or when it is advantageous to drain water vertically through an impervious to a pervious stratum. They are considerably more expensive than open ditches and are, therefore, of limited application in malaria control work. Tile makes the most satisfactory horizontal subsurface drain. Unflared concrete or vitreous pipe may be laid in the bottom of a narrow ditch with the ends butted together. The joints are left unsealed so that water can enter the line, but a strip of roofing paper or similar material is placed over the upper two-thirds of each joint to reduce silting-in. The ditch is then back-filled with rock and earth (Fig. 158).
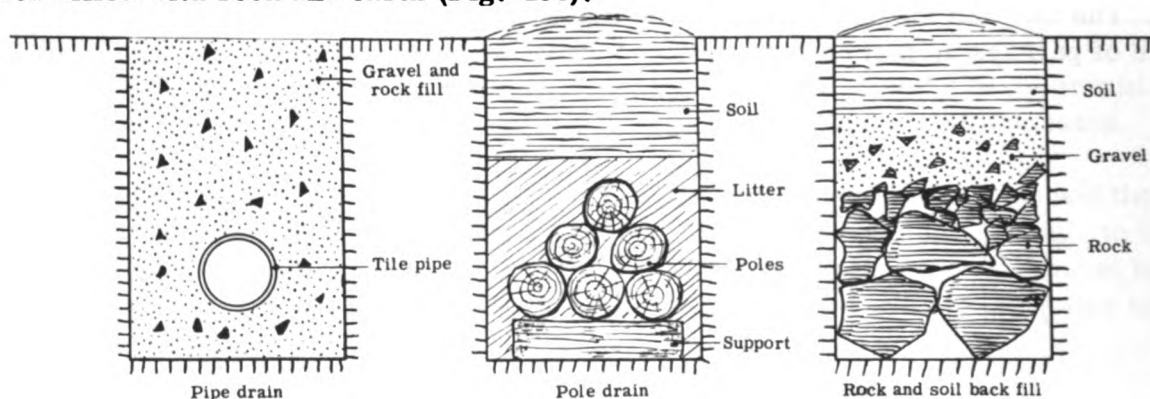
Figure 158.
Subsurface drains

If pipe is not available, large rocks or poles may be substituted. These are less satisfactory than pipe because soil eventually fills in the interstices and reduces the flow. In short, intercepting tile drains carryiny only seepage water, the grade may be 0; but where flood waters are to flow through the drain, a minimum grade of 0.3 per cent should be maintained to prevent silting. A grade in excess of 3.0 per cent may cause scouring.
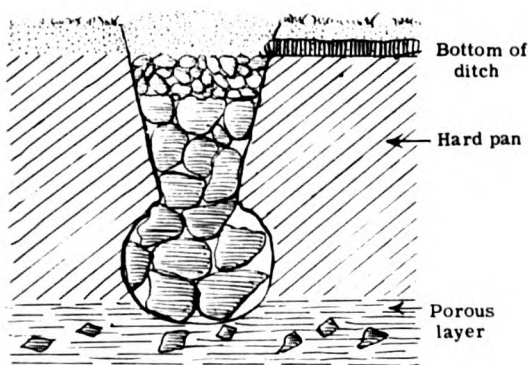
Figure 159.
Vertical rock-filled drain

Vertical drains (Fig. 159) are used to carry water through hardpan or other impervious strata into a porous stratum. They may be dug by hand or blasted and, in permanent installations, may be lined with masonry or concrete, if weep holes are provided. To maintain their efficiency, the drains should be cleared of silt deposits frequently.

238

Construction of Drains

Natural water courses may sometimes be so improved as to rid them of mosquito breeding. Removing obstructions, such as vegetation, fallen timber, and sandbars, and smoothing and correcting the side slope will increase the water velocity and reduce the breeding area. Wandering streams may be improved by digging or blasting a new and a straighter channel. The excavated earth from the new channel may be used to fill at least a part of each meander section. Filling should progress from the upper to the lower end of the sections in order to prevent the formation of blocked holes (Fig. 160).
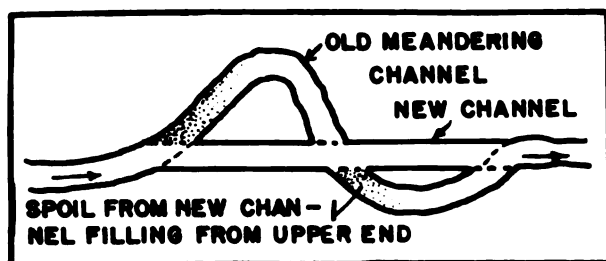
Figure 160.
Channeling

New Construction. Large ditches should be carefully surveyed and cross-sectioned and the yardage computed. Most hand ditches may be laid out without expensive refinements (see section on surveying and mapping). If adequte outfall has been determined, the ditch can be dug using the water in a ditch as a continuous surface for a perfect level. To obtain an accurate finished grade, batten boards are set across the ditch at intervals of fifty feet or less. Small stakes, set at about six-foot intervals, mark the center line of the ditch. The tops of these stakes are set on the finished grade.

All trees, stumps, or other obstacles that are in the proposed ditch right-of-way should be removed and placed where they will not interfere with spoil disposition or block drainage into the ditch. Usually it is best to begin operations at the outfall in order that the crew or machinery may work in a dry ditch. In clearing and cleaning old ditches or natural drainage systems, it may be wise to start up-stream and float the debris down-stream out of the way. It is important to determine that this floatage will not create problems down-stream. Ditches may be excavated by hand labor, blasting or machinery.

Ditching by hand labor is the most accurate means of constructing ditches, especially the small ditches that are so important in mosquito control programs. Ditches .constructed by dynamite or machinery usually require hand labor for dressing or finishing to accurate grade. In areas where labor is plentiful and cheap, as is usually found in foreign or occupied countries, hand ditching may be preferred to other methods. Ditches exceeding 3 feet in depth should be excavated by dynamite or machinery if they are available.

Dynamite ditches are frequently the most satisfactory types for malaria control in difficult terrain. In swampy areas where machinery would be impractical, dynamite is the method of choice and is less expensive than hand or machine excavations. (Fig. 161). Some other advantages are: a large quantity of earth can be moved in a short

239

period of time, at little cost, and with few laborers; it leaves no spoil bank and fits into a camouflage scheme better than other ditches. The grade and slope frequently need dressing by hand and it is not as satisfactory for use in dry soils as in wet areas.

The explosive most commonly used for ditchings is 50 per cent straight dynamite. This type is more sensitive than many other commercial explosives and must be protected from undue shock or heat. Because of its higher sensitivity, this type of dynamaite, when use in wet soil, can be exploded by propagation that is, a detonating cap is placed in only one stick, the remaining charges being exploded by concussion. In soils too dry and loose to fire by propagation, each charge must be primed. Gelatin dynamite is sometimes used for ditching, but it will not fire by propagation.

The spacing of charges and the number of sticks used in each hole will vary with the size of the ditch desired and the type of soil. The table below gives an approximate spacing. The depth of the ditch can be increased by using heavier charges and placing

Figure 161.
Dynamite excavation

them deeper. For a depth of 5 feet or more it is necessary to use two rows of charges. It is always well to make a test shot of 50 feet to determine the most effective spacing. In general, 1 pound of dynamite will move 1 cubic yard of soil. The following table may be useful in determining amount of dynamite for size of ditch.

Depth required in feet	Spacing of holes in inches	Depth of holes in inches	Sticks per hole
2	12	6	1/2
3	20	18	1
4	20	30	1 1/2

Holes are punched in the soil along the center line of the ditch. The charge is placed in the hole and covered with moist earth or water. The earth should be carefully tamped in the hole to remove air spaces. To prime a charge of dynamnite, a hole is poked in the end with a wooden stick and a blasting cap inserted as shown in Fig. 162. Electric blasting caps are usually preferred to fuse caps. They are wired for firing as shown in the same illustration. Stumps are removed by placing additional charge as shown in Fig. 162, each charge being primed.
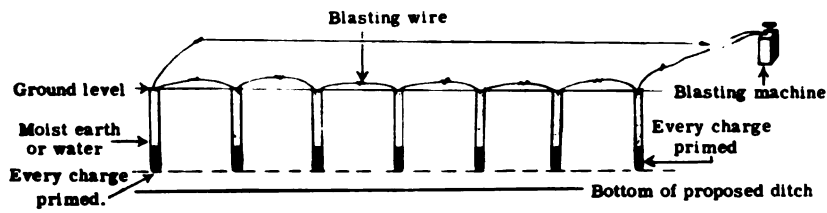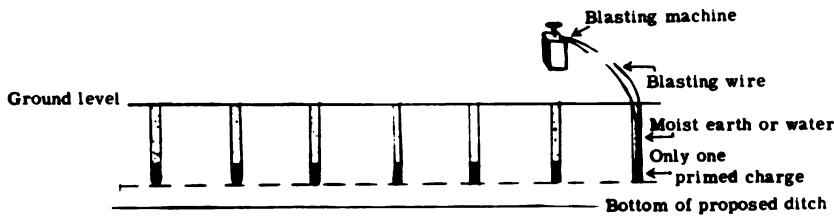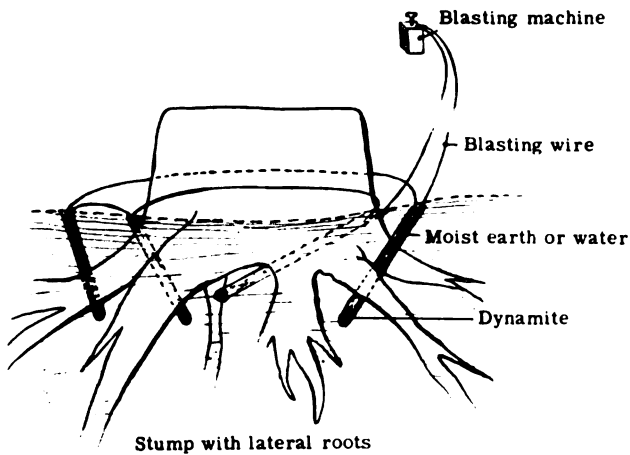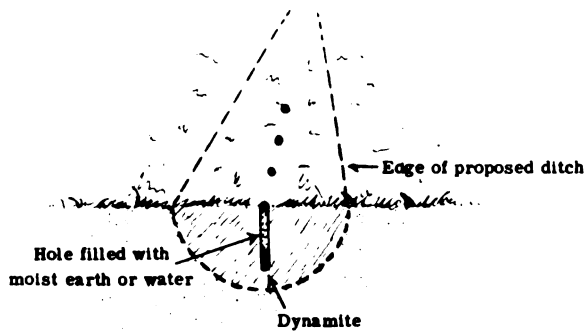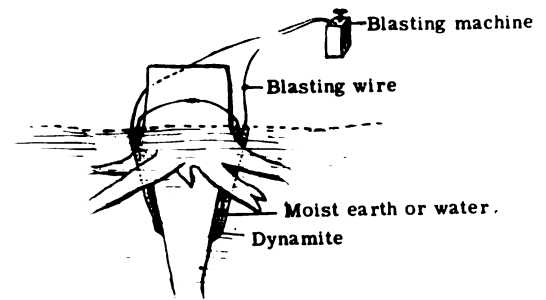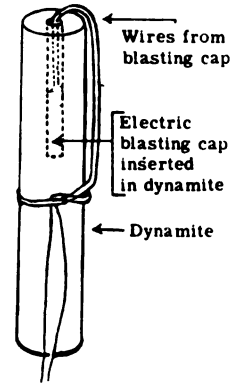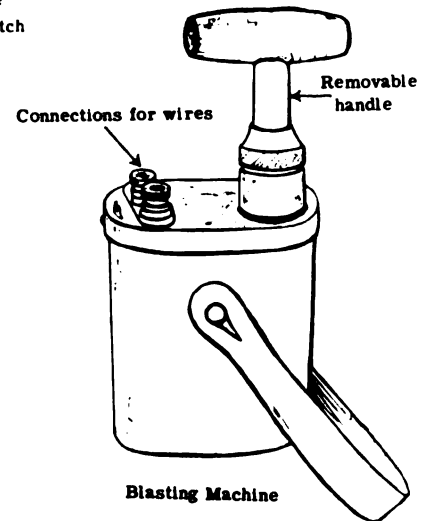
Figure 162.
Dynamite ditching

Explosives are dangerous in the hands of inexperienced persons. Wherever possible, dynamiting should be done only by an experienced blaster. If it is necessary for an inexperienced person to handle dynamite or detonating caps, he must first acquaint himself fully with proper procedures and then adhere to such procedures rigidly.

241

Machinery is required for excavating large drainage ditches. Although heavy equipment is faster than ditching by hand labor, it is not as accurate in grade and cross section. Examples of equipment for excavating ditches include plows (especially gasoline powered terrace disk plows), ditch digging machines, road graders, bulldozers, back hoes, and draglines.

The dragline (Fig. 163) is the most useful machine for digging large ditches. It can be used on either dry or soft ground. In the latter case, plank mats must be used to keep the machine from sinking. A good operator will dig 200 to 1,000 feet of ditch per day, depending upon the size of the ditch and the soil conditions. A dragline cannot be used efficiently where the depth of the ditch is less than 2 feet. Back hoes are used in much the same way.

Bulldozers and road graders are useful for constructing shallow, wide ditches in open terrain (Fig. 164). Such equipment operates best in constructing new ditches in dry seasons. Bull dozers are frequently used in conjunction with draglines for spreading the spcilbank.

A ditch-digging machine, primarily used in pipe line work, is sometimes employed in drainage work. Most of these machines make a ditch with vertical sides and dispose of the spoil in a continuous bank. For mosquito control projects the slopes have to be dressed by hand and the spoil bank spread or broken at frequent intervals. This entails almost as much work as excavating the drain entirely by hand.

Figure 163.
Dragline in operation

Figure 164.
Bulldozer in operation
(note armored shield
fnr driver)

242

A terracing plow is useful for making a shallow ditch in open areas, especially if the ditch is laid out slightly downgrade from the natural contour line of the terrain.

Drain maintenance is necessary in almost every type of construction. Some up-keep is required even for those systems that have been lined with concrete. The open unlined ditch requires frequent inspection and maintenance to deal with obstructions, bank erosion and growth of vegetation. The frequency of ditch cleaning and repairs depends on local conditions. Most extensive repairs should be carried out during the winter months when labor use is not so demanding. Various accessory structures, such as rip-rap, linings, and culverts, may be built into ditches to reduce mainten-ance and improve the flow of water.

Rip-rap is the term applied to any armor placed along the bank of a ditch to pre-vent erosion (Fig. 165). It is used to deflect currents around the outer side of a sharp curve or at ditch connections; or to strengthen the side of the ditch where the soil is loose or where an appreciable flow of subsurface water enters the ditch through the bank. Rip-rap may be made of logs piled one on top of the other and staked in place, or of masonry blocks concreted together, or of loose angular boulders of sufficient weight to resist movement by the current.

Protection of ditch banks by rip-rap

Profile of ditch showing use of step to reduce grade

Steps of concrete or wood
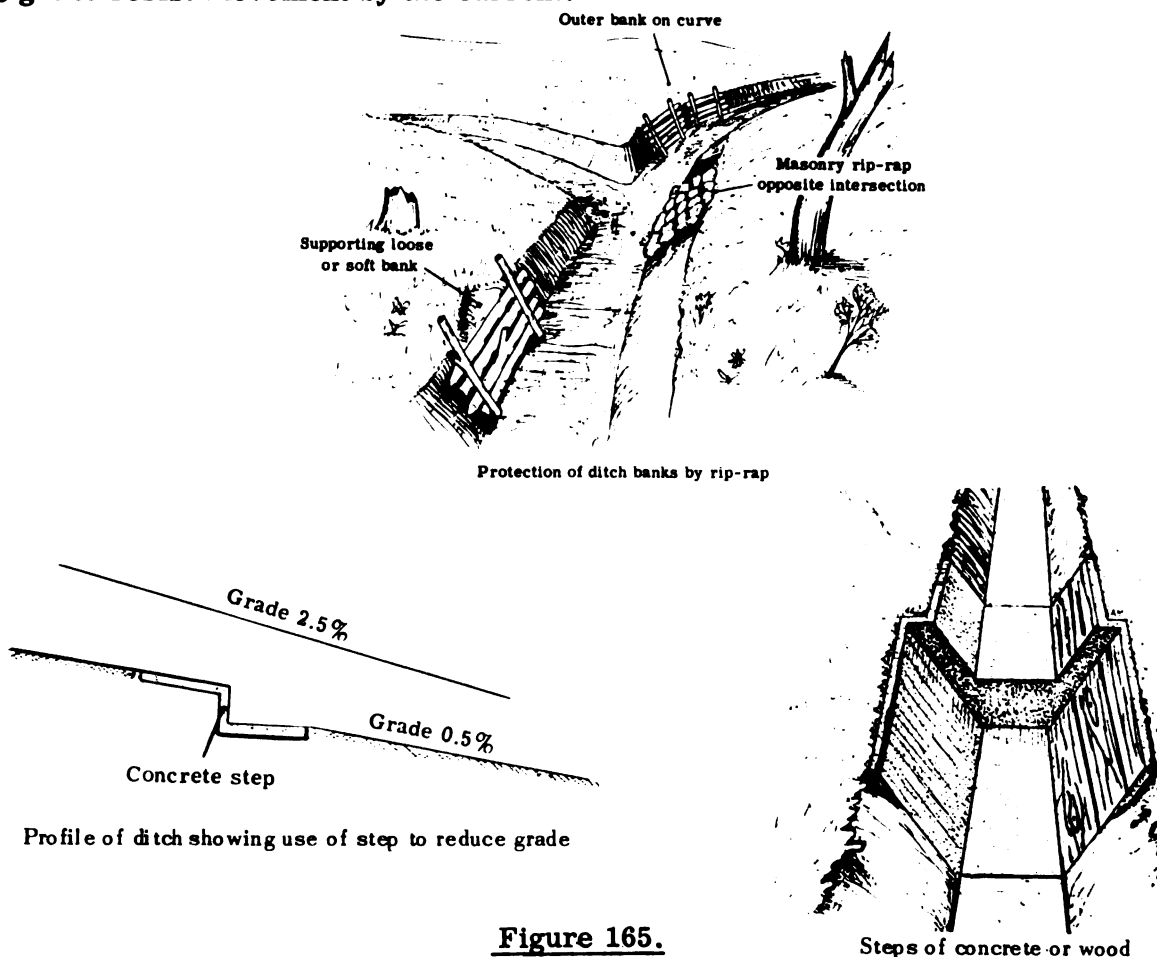
Figure 165.
Various accessory ditch structures

243

Where the water carries a large amount of suspended soil, <u>sand traps</u> or <u>silt basins</u> (Fig. 166) are great aids in keeping ditches and subsurface drains clear. They should have sufficient volume to retain the water long enough for the silt to settle out and to allow sufficient working room for cleaning.

Baffle plate

Sand settles here
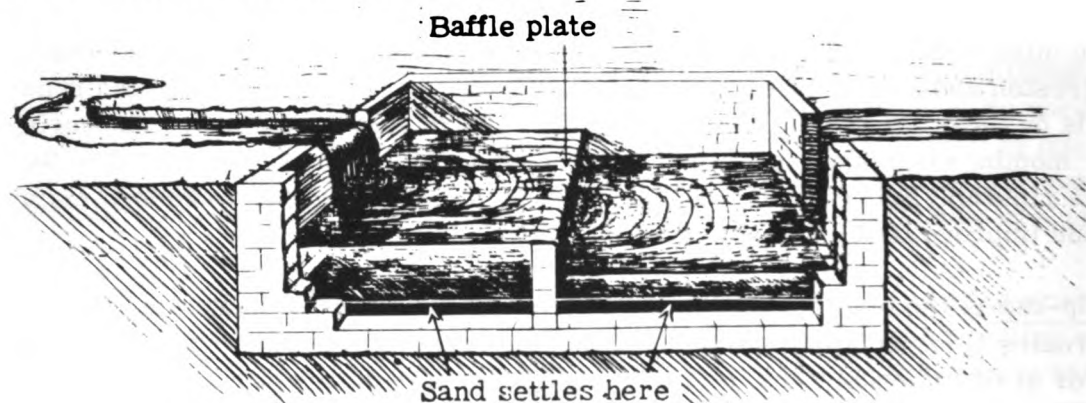
Figure 166.
Sand trap or silt basin

<u>Steps or drops</u> are used to reduce grade where it is impractical to do so by increasing the depth of the ditch. Steps may be made of wood, but concrete or masonry is better. Whenever steps are used, they must be properly constructed; otherwise, erosion and silting may render the ditch valueless. The step must have a secure footing in the bottom and sides of the ditch. Aprons must be provided both above and below the step. The lower one should have a zero grade and there should be weep holes to relieve any seepage pressure from above (Fig. 165).

<u>Vegetation removal</u> from stream or ditch banks and from pond or lake shores is required (except in control of certain mosquitoes with shade). Usually this must be done by hand labor using hand tools. Mowing machines are useful in shallow ditch areas. In areas where extensive drainage systems require vegetation removal, a trailer-mounted, gasoline-driven weed burner may be employed. A satisfactory hand weed burner can be improvised by utilizing a decontamination type sprayer with a long hose and a 6 foot extension nozzle. A wire clip extends 6 inches in front of the nozzle for holding an oil rag. After diesel oil is sprayed on the rag, it is set on fire to serve as a pilot light. A good flame for weed burning is obtained using the fine cone-shaped spray. During the first round with a weed burner, it is not necessary to burn until the vegetation is consumed by the fire. A little fire will kill the grass and weeds which will be totally destroyed during subsequent burning. Careful vigilance is required to prevent uncontrolled fires from starting and fire-fighting equipment should be available for immediate use.

<u>Herbicides</u> are available that may be used to advantage in the control of vegetation on shores and in the water. The hormone type of herbicide or arboricide has many

advantages over the non-hormone vegetation killers. Many of the latter contain poisons that may be hazardous to man, livestock and fish. Small-scale field experiments should be conducted with herbicides before they are utilized extensively against the objectionable plants to be controlled.

Ditch linings are used to prevent both side and bottom (invert) erosion (Fig. 167). Invert linings, which serve to protect the bottom of the ditch, may be made of wood, oil drums cut in half longitudinally, masonry blocks cemented together, or concrete. If made of concrete, they may be precast or poured directly into the carefully prepared ditch bottom. Expansion joints are necessary for masonry or poured concrete invert linings. "Weep holes" should be provided in any type at points where seepage water enters. Each section of invert lining should be anchored to the ground by a footing. A carpeting of short grass makes an excellent lining for the portion of the ditch above the water line; it has the advantage of being better anchored to the bank than riprap. Bermuda or similar grass is excellent. It may be established by sodding or by rooting scattered plants. Water and fertilizer may be necessary. Full concrete linings are installed only in permanent systems and their construction should be supervised by an engineer.
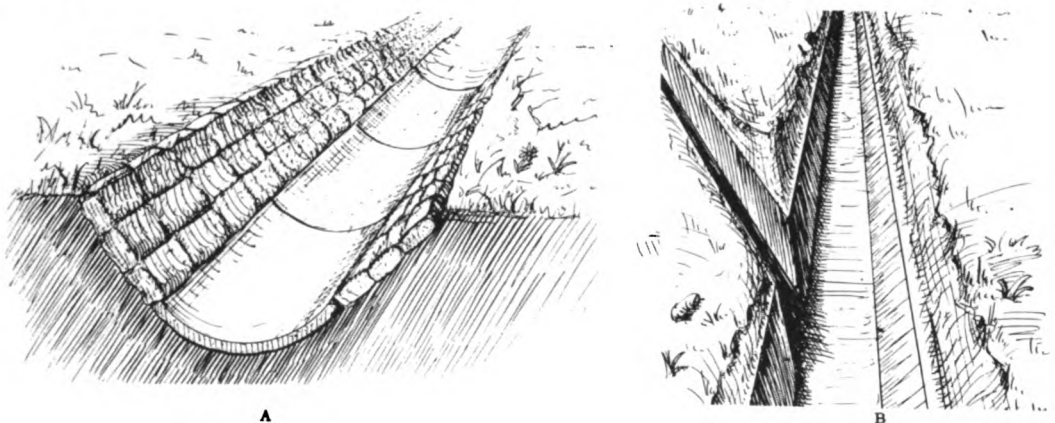
Figure 167.
Ditch linings. A. Concrete invert lining and grass sodding. B. Full concrete lining

Pipe and box culverts are used to conduct water under roads or other embankments. They are made of wood, concrete, or currugated iron. Corrugated iron is preferable, since it will better withstand settling and other stresses. Culvert pipes can be improvised by cutting the heads out of oil drums. These work satisfactorily provided the weight of fill and traffic is not great enough to crush them. It is important to place culverts properly to prevent the formation of residual pools of water that may become mosquito-breeders. They should always be placed on the line and grade of the stream or ditch. (Fig. 168). The size of the culvert should be adequate to carry high water volumes. When a large size is not available, two or more of a smaller size may be used, side by side. Proper footing should be provided to prevent settling particularly where the culverts are covered by a heavy fill. When necessary, wingwalls or rip-rap may be built around the ends of the culvert to prevent washing around the outside.

245

Line of natural flow

Road

Incorrect   Correct

Placement of culverts

Road   Road

Culvert on grade of flow   Up stream end too high   Standing
Correct   Incorrect   water

Road   Road

Sand and gravel

Culvert level tending to fill   Down stream end too low

Standing water   Incorrect
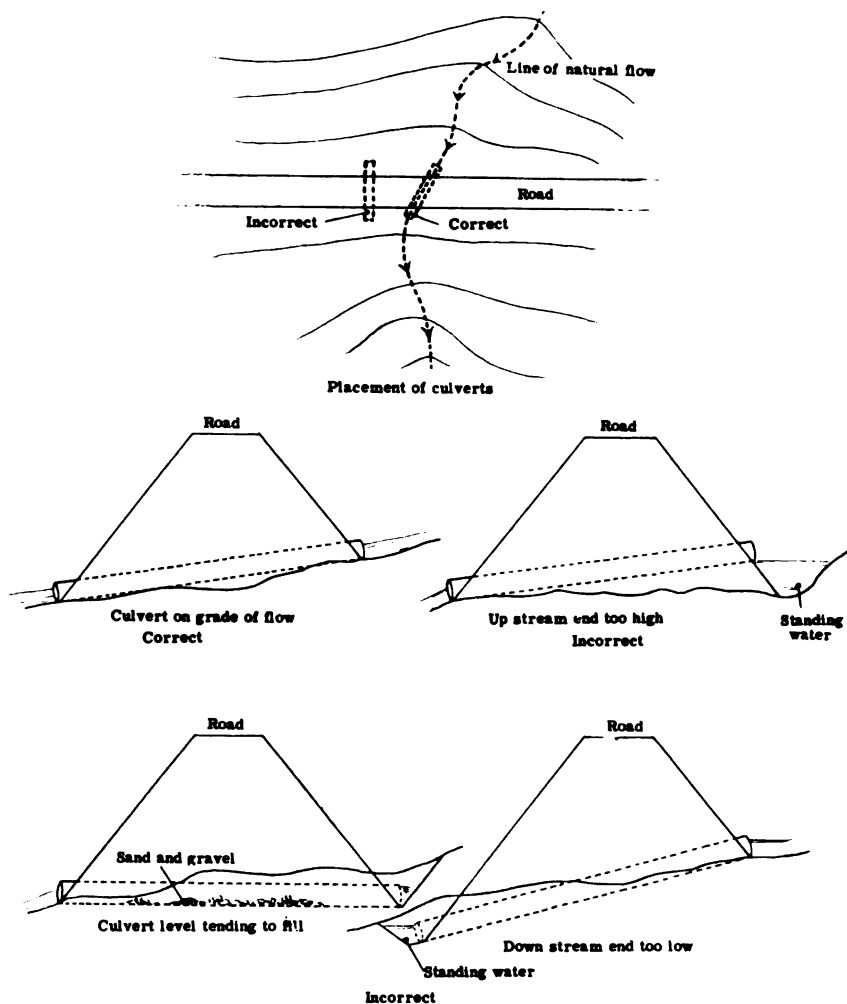
Figure 168.
Correct and incorrect installation of culverts

Pumps and sumps are frequently used to drain areas too low for drainage by gravitational flow. Some shallow swamps and temporary breeding areas can be most easily dried by pumping the water into a stream or onto porous dry ground. This is a temporary procedure and must be repeated whenever sufficient water accumulates to permit breeding. Pumping may also be necessary on drainage projects when the level of the drained area is below the low-water level of the adjacent stream. Such situations require the installation of a sump (pool in which to install a pump) and a continuous or automatically operating pump of adequate capacity. Such an installation would ordinarily be justified only in a permanent control project.

Tide gates may be used to prevent tide water from backing into natural water courses or ditches. The gate is hung on a culvert or head-wall and operates like a simple check valve. When the water on the upstream side is low, the pressure of rising tide on the seaward side closes the gate; at low tide, the water pressure on the upstream side opens the gate. Tide gates should be placed low enough to permit maximum drainage but high enough to prevent their being blocked by sand deposits from the

246

sea. The gate itself is usually made of 2-inch plank and preferably of clear, well-seasoned stock. The size should not exceed 36 by 36 inches. Where a larger discharge orifice is required, use two or more gates side by side. The hinges should be so constructed as to tolerate a certain amount of springing without injury. Otherwise, if flotage or other debris should be caught between the gate and the seat, the hinges will be permanently damaged and the gate will no longer close properly. Sluice gates may be used to impound and release water as desired. The gate is hung in guides set in a head-wall or culvert and is raised and lowered manually (Fig. 169).
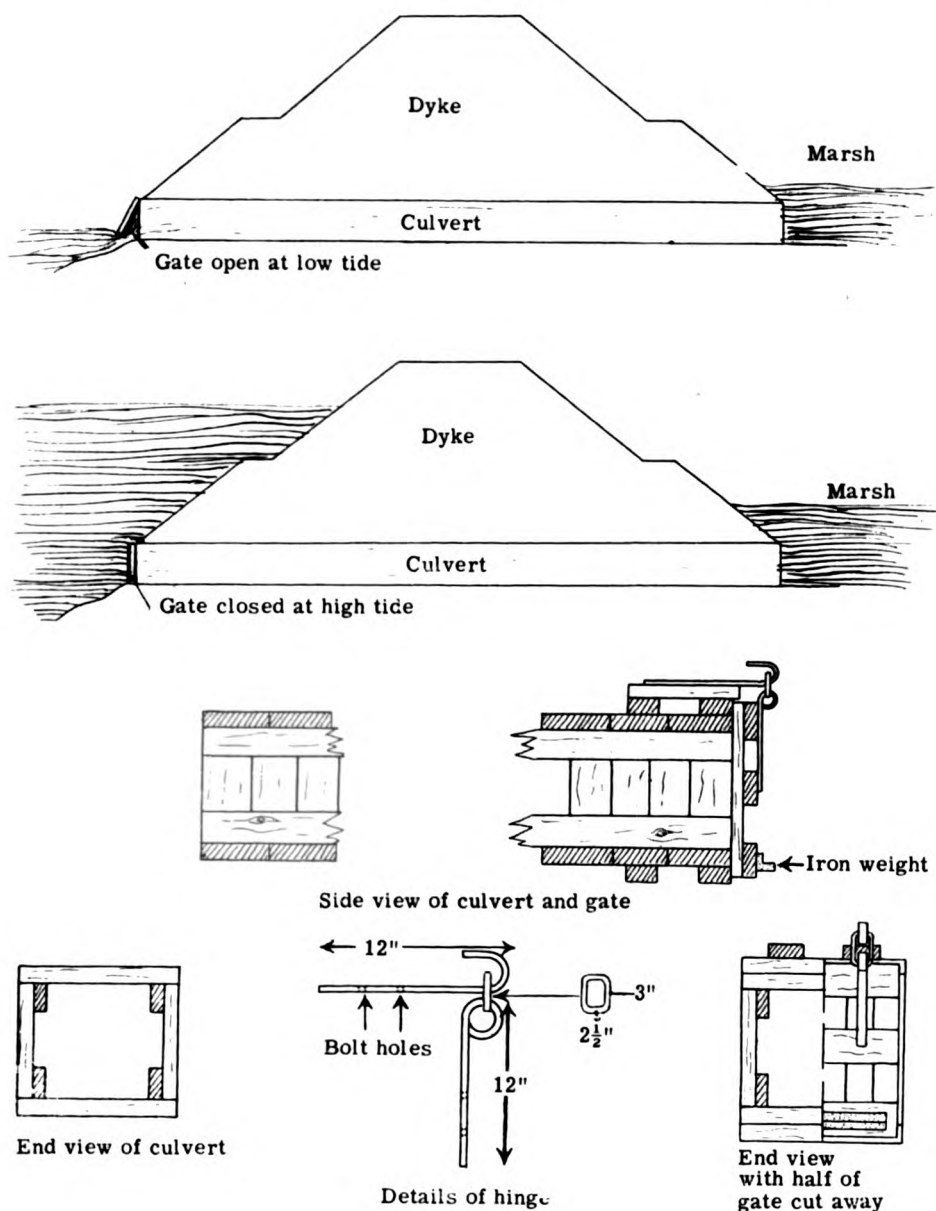
Figure 169.
Placement and construction of tide gate

Flumes between swamps or lagoons and a bay often become blocked by sand washed in by the surf. Such areas just back from a beach offer ideal breeding places for many mosquitoes. Frequently such a condition is caused by wave action which builds up a sand bar across the mouth of a stream to form a dam. Breakwaters and arrow heads may be installed to retard the formation of such barriers (Fig. 170). Periodically, the water in the stream increases to the extent that a break through will occur or a ditch may be installed to provide an outlet. Usually, wave action will again build up the sand bar and the work must be repeated. Flumes constructed from any type of culvert material may be installed to provide a free outfall (Fig. 171). Empty 55-gallon oil drums, cut and welded together may be used in the absence of other materials (Fig. 172). Such an installation usually provides tidal action and alternating fresh and salt water which inhibits mosquito development.
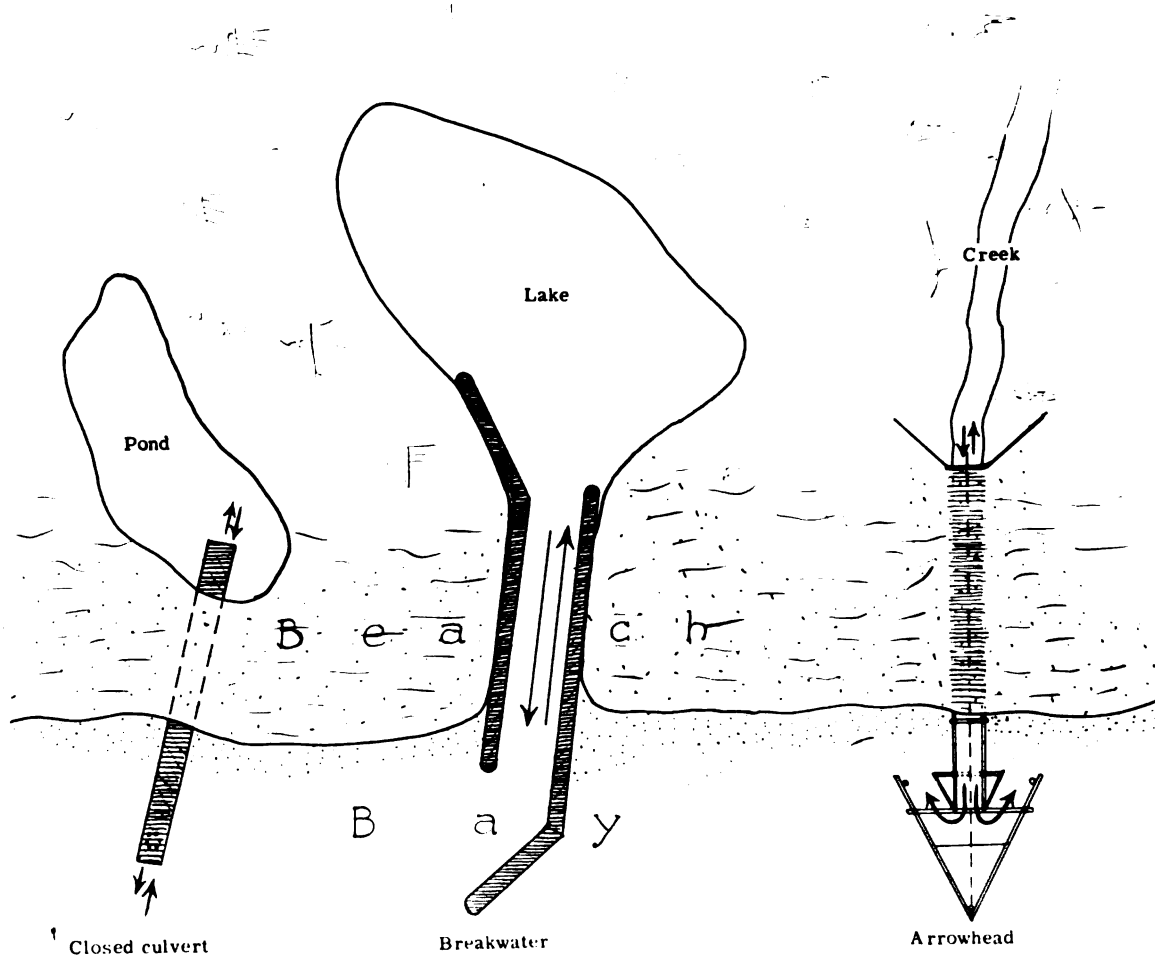
Figure 170.
Structures to retard formation of beach barriers

Figure 171.
Oil-drum culvert for draining lagoons

HIGH TIDE
LOW TIDE
F L PIPE
1'- 0" MINIMUM

CULVERT MADE OF OIL DRUMS

LONGITUDINAL SECTION

NORMAL FLOOD BREAK—THRU POINT

FLUME IS PLACED WELL AWAY FROM THIS
POINT TO AVOID WASHOUTS FROM HEAVY
RAINS.

NOTCH PILES FOR SUPPORTS
AND BRACES

TRANSVERSE SECT.
6" TO 8" PILES APPROX. 5-0.
2"x 6" SUPPORTS AND BRACES.

LOW TIDE

LAGOON

←HIGH TIDE→

OCEAN

BEACH

PROTECTIVE PILING

PLAN

FLUMES ARE ASSEMBLED IN FIVE (5) DRUM SECTIONS.
ONE END OF EACH SECTION IS SPLIT AND DRAWN IN
TO TAPER FOR SLEEVE FIT WITH ADJOINING SECTION.

Figure 172.

249

Filling and grading. The most permanent means of eliminating many mosquito breeding areas is by means of earth fills. Under ordinary circumstances this method may also be the most expensive. Frequently, cooperation with other engineering activities will permit filling of some areas at little or no cost. Also such reclaimed land increases in value and may be utilized as parks, playgrounds, golf courses or airfields.

Wet or hydraulic fills may sometimes be utilized without excessive cost. Low areas near harbors and river channels being improved by hydraulic dredging frequently may be filled with the excavated mud from dredging effluent at no cost to the mosquito control program. Mud or silt bearing streams may be diverted and tracked so that the silt will be deposited in mosquito breeding areas.

Dry fills may be utilized in many areas to eliminate permanently a water holding depression. Bulldozers and carryalls are excellent for dry fill operations (Fig. 173). Sometimes excess earth from road or building projects may be utilized for land fills. Municipal rubbish is used in some areas for land fills and then covered with earth.

Figure 173.
Bulldozer in operation

250

<u>Grading</u>. Man is the frequent culprit for causing mosquito breeding areas. Military operations are especially prone to produce water holding depressions. Fox holes, tank tracks, and truck ruts are examples of such conditions. Bulldozers, road graders, even disc or section harrows may be used to grade and smooth areas with excessive ruts, pot holes or other small depressions.

Management of Water

<u>Water level fluctuation</u> in reservoirs does at least three things: Strands aquatic stages at the margins; dislodges larvae from vegetation and flotage so that they are more exposed to wave action and fish; and discourages plant growth and strands flotage in the fluctuation zone. Variation of pool level is usually managed to produce a gradual drawdown during the entire breeding season (<u>seasonal recession</u>), or a regular fluctuation between constant limits (<u>cyclical fluctuation</u>), or any combination of these two. The interval of change must be less than the length of life of the larvae and is usually from 7 to 10 days. In the case of cyclical fluctuation there is usually a drawdown of about 1 foot followed by a refilling to the original level.

Irrigation systems often are troublesome, mainly because of poor construction and improper management. The irrigation of rice fields presents a special problem. Apparently, the best control system for them is <u>periodic drying</u>; one common practice involves 9 days of flooding and 2 days of drying.

<u>Flushing</u> is employed in rather small streams and channels where there is a continuous and plentiful supply of water flowing slowly enough to permit breeding. Mechanical devices, gates and siphons, are constructed to provide for the periodic damming and discharging of water. This is done in order to discharge large enough volumes of water at least once a week to wash the larvae, pupae, and eggs downstream or to strand them high on the banks. Muddying of the stream by the rush of water probably has a further deterrent effect on breeding. Sluice gates may be either hand or machine operated, and siphons should be automatic. An automatic stream siphon is illustrated in Fig. 174.

<u>Flushing dams</u> are constructed on suitable streams to build up a head of water which, when suddenly released, rushes down the stream bed, washing out larvae and flotage, and retarding growth of bank vegetation. Dam sites are chosen at spots where the channel is narrow and the banks high enough to allow impounding of water to a depth of about 4 feet. Some dams are designed for automatic flushing (Fig. 174), but most are built for manual operation. Accessory work includes clearing and trimming of the stream banks below the dam and as far above as the impounded water extends; this eliminates side pools for breeding. Flood waters during the rainy season may wash out these dams, and the gate is therefore removed during the rainy season.

251

TOP OF DAM   PIPE OUTLET

TROUGH   SIPHON

                                 EDGE
                                 OF DAM

**SIPHON IN DAM AS SEEN
FROM DOWN STREAM**

¾" PIPE CAST   2" REINFORCED
IN CONCRETE   CONCRETE

                      X

AIR POCKET   PIPE EXTENSION

3'   DIRECTION OF FLOW
                      WATER LEVEL

WATER SEAL
IN TROUGH   Z
PIPE
OUTLET

Y
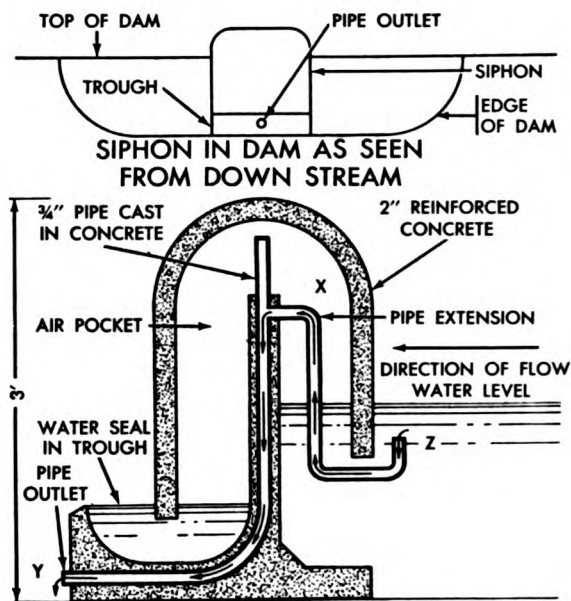
A
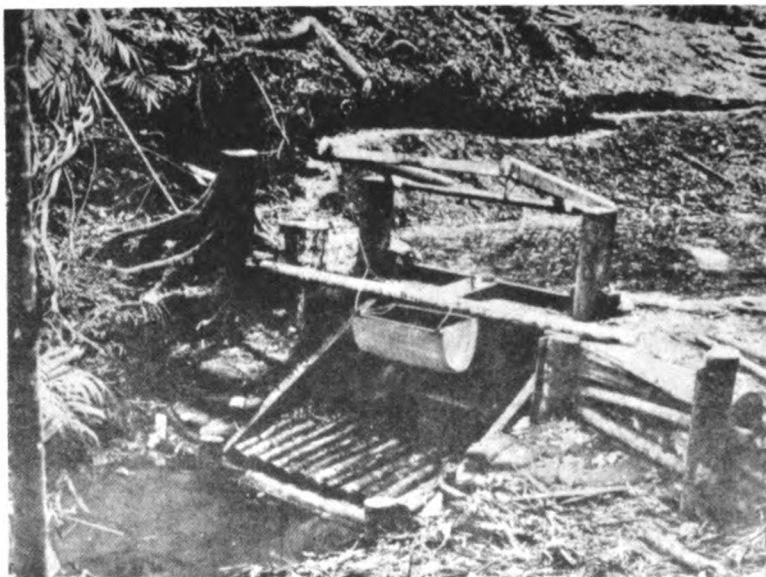
B

Figure 174.
Two types of stream flushing devices.
A. Diagram of automatic siphon
B. Automatic gate

252

SURVEYING AND MAPPING

Some knowledge of surveying and mapping is essential in planning and carrying out a malaria control program. Suitable maps of the control area are indispensable for organizing the oiling and drainage program and for recording daily progress. Breeding areas, native villages, and areas occupied at night by troops should be clearly indicated, as well as adult collecting stations, larval-dipping stations, and orientation points, such as roads and hills. Colored pins or flags may be moved about on a wall map to indicated the current situation in regard to breeding, oiling, drainage, and the appearance of malaria cases. If satisfactory maps are not available, they must be prepared. In addition, an ability to conduct profile surveys of swampy or ponded areas is required in order to lay out an efficient drainage system.

Methods of Measuring Distance and Direction

The branch of surveying employed in malaria control work is called plane surveying because the over-all surface of the earth is considered to be flat rather than spherical. Since the actual curvature of the earth is only about 0.7 foot per mile, no appreciable error is introduced in surveys involving a radius of less than 5 miles. Surveying for malaria control is confined almost exclusively to measuring horizontal distances, determining the direction of horizontal lines, and measuring vertical distances (elevations).

The horizontal distance between any two points is the air-line distance, not the distance that would be traversed in going up and down hill. Therefore, horizontal distances must be determined either by a series of horizontal measurements or by measurements along the slope taken in such a way that they can be converted to horizontal distances. Common methods of horizontal measurements used in malaria control work are: Visual estimate, pacing, and chaining. Visual estimate, "taking distance by eye," is used only for rough approximations where speed is more important than accuracy and where visibility is not obstructed. Pacing or stepping off the distance between two points is a rapid method of determining horizontal distance and is sufficiently accurate for most mapping surveys. The length of stride must be known. In measuring distance by pacing, it is important to keep on a straight line and to maintain the same length of stride on even and on uneven ground. Where rises and depressions are traversed, allowance must be made to correct the slope distance to horizontal distance. With practice, it should be possible to pace distances with errors not exceeding 50 to 150 feet per mile. The amount of correction to make for different slopes can be learned by experience, but the table given below will help the beginner. For every 100 feet measured up or down a slope, the true horizontal distance will be:

Rise or fall in feet per 100 feet	:	10	:	20	:	30	:	40
Horizontal distance -- feet	:	99.5	:	98.0	:	95.4	:	91.7

Chaining or taping is the measuring of horizontal distance by means of a tape. This method is used when pacing is not sufficiently accurate. Three kinds of tapes are commonly used: Cloth, metallic cloth tapes having fine wires woven into the fabric to reduce stretching, and steel. The 100-foot length is most commonly used in engineering work. For convenience in calculation, engineers' tapes are graduated in tenths and hundredths of a foot, rather than in inches. The procedure in chaining the distance between two points is as follows:

1. Visible markers, such as long stakes, are set up at both points.

2. At the point of beginning, one man (the head chainman) takes the 100-foot end of the tape and walks along the line the length of the tape.

3. A second man (the rear chainman) holds the zero mark at the point of beginning. The head chainman pulls the tape tight and the rear chainman motions him on line by sighting on the marker at the far end of the line.

4. When the tape is properly on line and the zero mark is on the beginning point, the head chainman puts a marker (nail or peg) in the ground at the 100-foot mark on the tape.

5. Both men now move ahead 100 feet and the procedure is repeated to mark a distance of 200 feet, and so on until the entire distance has been measured. It is important that an exact count be kept of the number of 100-foot measurements made.

When measuring on sloping ground, the tape must be held horizontally and the distance transferred to the ground by plumb lines. If the slope is so steep that the lower chainman cannot reach high enough to hold the tape level, the distance must be measured in shorter sections, 50-, 25-, or even 10-foot lengths.
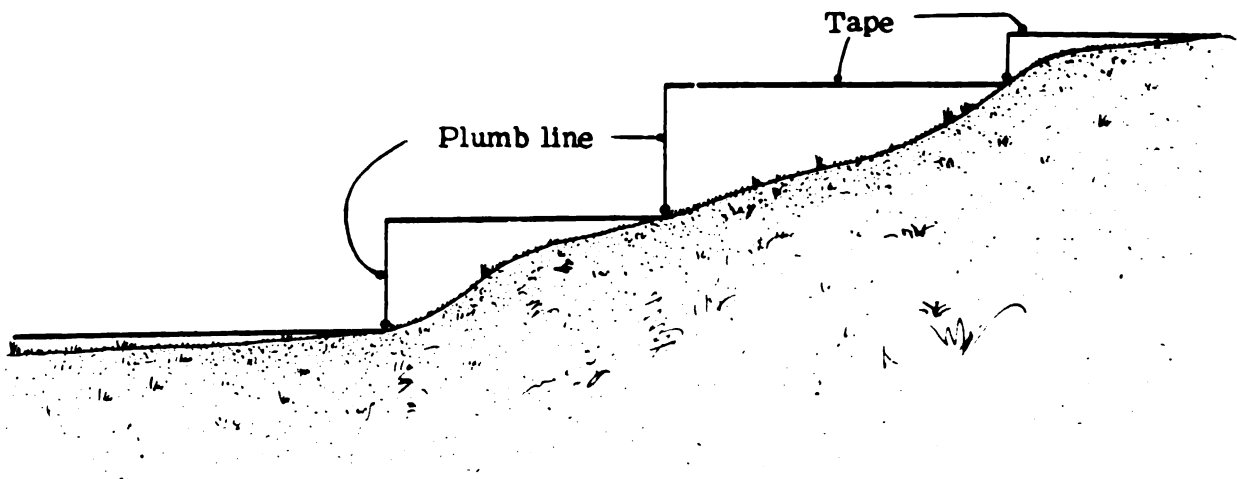
Figure 175.
Chaining horizontal distance on sloping ground

254

When there is an obstacle on the line of measurement, vertical or horizontal off-sets must be made. A vertical offset is made by plumbing; a horizontal offset, by laying out 90° angles around the obstacle. A 90° or right angle can be laid out with a tape by making a triangle having the sides in the proportion of 3:4:5. For example, in figure 176, if the 0-foot and 48-foot marks are held at A, the 12-foot mark at C, and the 28-foot mark pulled out so that a triangle is formed, the angle C will be a right angle.

If a line is to be marked for further survey work, short stakes should be driven into the ground at the beginning point, at each 100-foot interval, and at such inter-mediate points as required. Stakes are driven vertically with the wide side across the line, and the distance from the starting point is marked with crayon on the rear face. The beginning point is marked 0 + 00, the stake at 100 feet, 1 + 00. A stake at 165 feet would be marked 1 + 65; at 345.2 feet, 3 + 45.2 The points at even 100-foot inter-vals are called stations, those at intermediate points, pluses. The following are the most common mistakes and errors in chaining: Poor alignment, not pulling the tape tight, careless plumbing, failure to use the correct zero mark on the tape, incorrect count of 100-foot lengths, and incorrect reading of the figures on the tape.
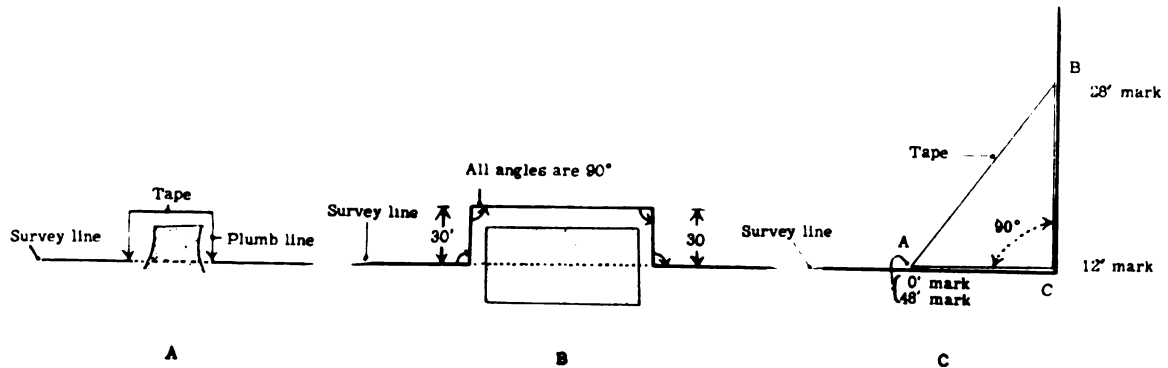
Figure 176.
A. Chaining over low obstacle. B. Chaining around building.
C. Laying out a 90° angle by means of tape.

Measuring Direction: Direction of a horizontal line is usually expressed as the angle of intersection with true north or magnetic north. True north is the direction from any point toward the North Pole and is used only in surveys requiring a high order of precision. Magnetic north is the direction indicated by the north-seeking pole of the horizontal magnetic needle. The angle of divergence (easterly or west-erly) of magnetic north from true north is called magnetic declination. The amount and direction of declination varies from place to place, and in any one locality is sub-ject to a small annual change which can be predicted from past records. On standard military maps, magnetic declination in the area represented is given graphically as shown in Fig. '   . In field work, direction is usually based on magnetic north because it can be quickly determined by means of a magnetic compass.

255

22° 5" East

Magnetic
North

True
North

Approx. mean declination 1937
Annual Mag. change 2"decrease
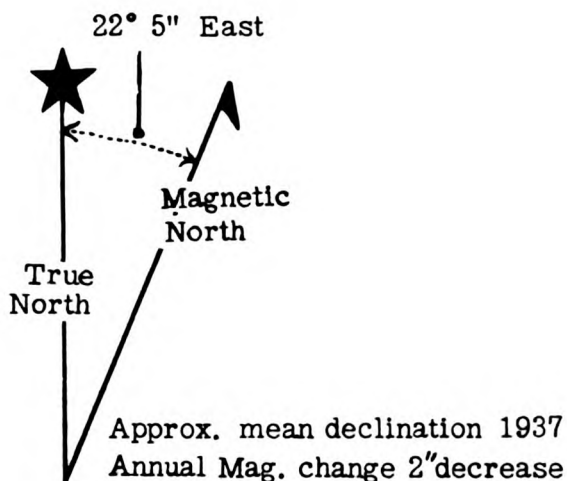
Figure 177.
Graphic representation
of magnetic declination

Pocket compasses are commonly used in surveying for malaria control work. The standard <u>marching compass</u> has a floating dial mounted on top of a magnetized bar. The dial has two scales of graduation, the outer scale is in mils (0 to 6,400), the inner one in degrees (0 to 360). Both scales have the 0 at the north point and the graduations increase in a clockwise direction. The mil scale is used only for certain military problems. To determine the direction of a line to an object, the object is sighted as shown in Fig. 178B and the angle from magnetic north read through the lens on the rear sight. The graduations are such that the angle is always measured in a clockwise direction from magnetic north; thus, due east is 90°, due south 180°, and due west 270°. A direction expressed in this manner is called a <u>magnetic azimuth</u>. When direction is taken by sighting back along the line (in the opposite direction from which the line is being run), the angle is called the <u>back azimuth</u>. The difference between the azimuth and the back azimuth of any line is always 180°.
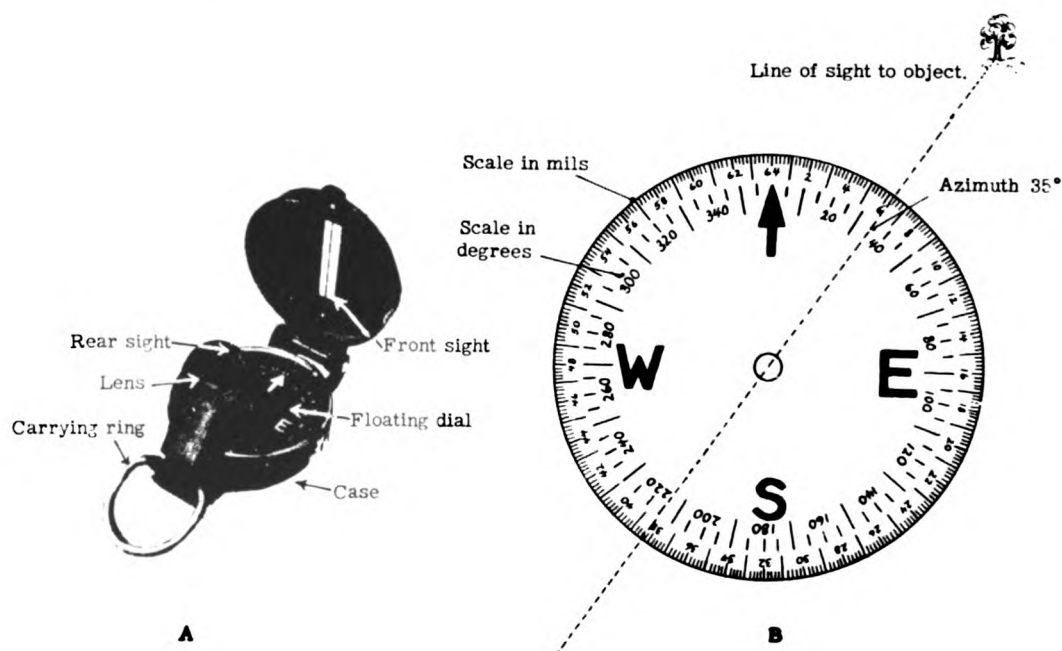
Figure 178.
Marching compass. A. Open for use. B. Diagram of floating dial and line of sight

The underline surveyor's pocket compass underline differs from the marching compass in having the graduated scale fixed to the base of the case and the magnetized needle supported on a pivot above the scale. The circle is usually graduated in quadrants of 90° from the north and south designations. The east and west designations are reversed from their normal positions so that when the sighting line is pointed toward an object, the direction can be read directly from the graduation to which the north end of the needle points. The direction will be expressed as degrees east or west of magnetic north or magnetic south. Direction taken with a surveyor's compass is called the underline magnetic bearing underline.

Magnetic compasses may be affected by local underline attractions underline; that is, the magnetic element may be attracted toward a near-by iron fence, steam line, or iron ore deposit. Compass survey lines must avoid sources of local attraction.
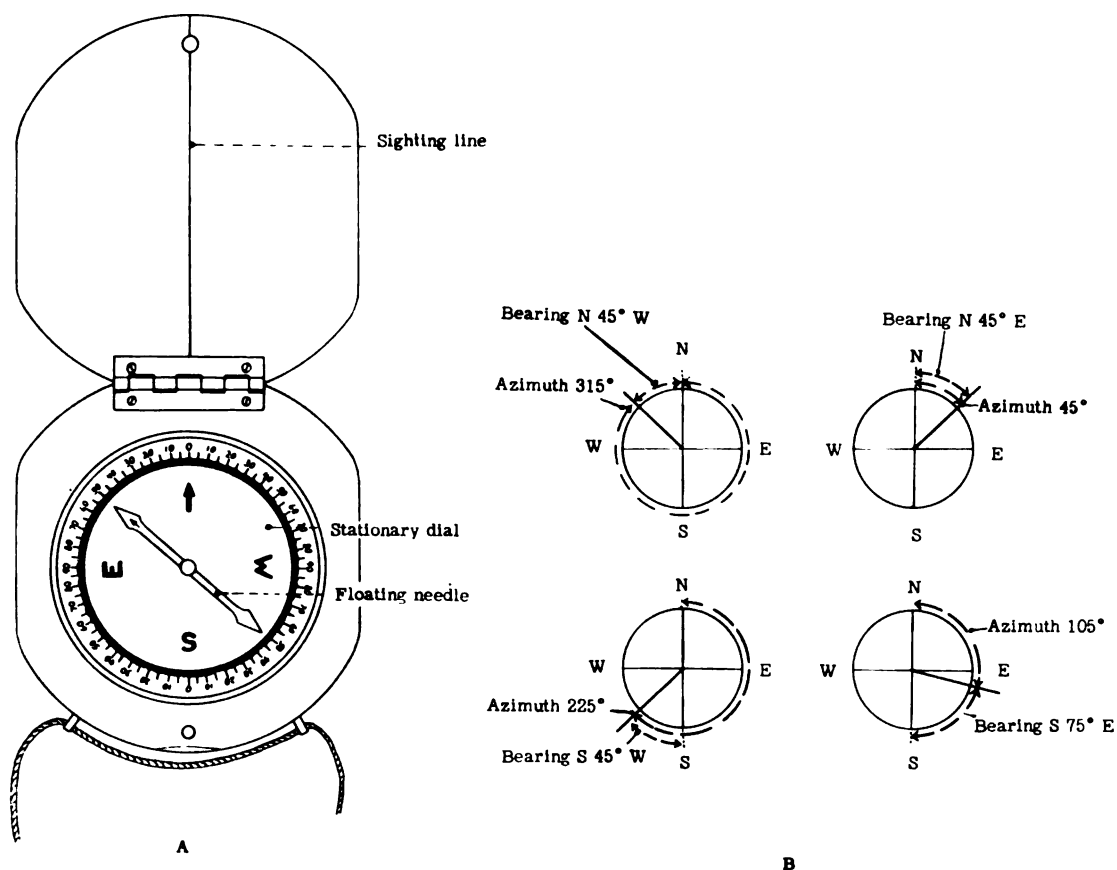
Figure 179

A. Surveyor's compass. B. Comparison of magnetic azimuth and magnetic bearing

Mapping

A map is a graphical representation of a part or all of the earth's surface. It is a plane projection, thus representing a vertical or bird's-eye view, and is made to

257

scale so that all distances on the map are proportional to the distances they represent on the ground. The amount of detail shown and the accuracy with which a map is made should be determined by the purpose for which the map is to be used. All details of the terrain pertinent to malaria control should be shown. These should include swamps, water courses, ponds, ditches, camp sites, and native villages. In addition to the necessary detail of the area represented, all malaria control maps should carry the following information:

1. Identifying title (Naval Advance Base X -- Malaria Control).

2. Maker and date made (Made by John Doe, HM2, 3-1-58).

3. Source and date of data (Aerial Photo No. 5704 or Compass and Pacing Survey, 2-15-58).

4. Scale (Scale 1" = 500'; or Representative Fraction* 1:10,000.

5. Orientation (Direction) -- a line showing magnetic and/or true north with magnetic declination if known.

6. Legend -- identification of symbols used.

Diagram of a closed traverse survey

Points 1,6 - Located by offset
Points 2, 3, 4,5 Located by radiation.
Point 7 - Located by intersection.
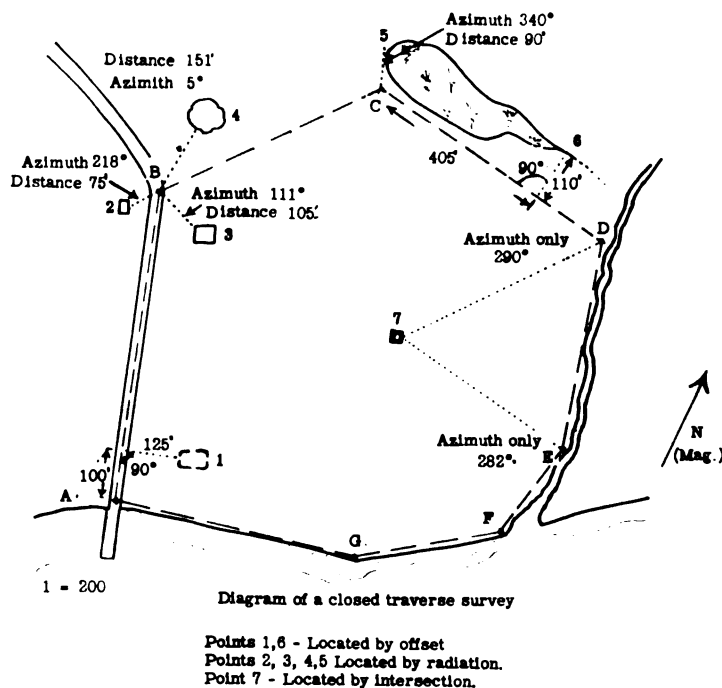
Figure 180.
Diagram of closed traverse survey

* Representative fraction 1:10,000 means that 1 unit of length on the map equals 10,000 of the same unit on the ground; 1 inch equals 10,000 inches; 1 foot equals 10,000 feet.

253

Compass and Pacing Survey John Doe Dock Area - Advance Base X			
Station	Azimuth	Back Azimuth	Distance
A - B	343°	165°	650'
1	(offset)		100'/125'
B - C	39°	217°	497'
2	218°		75'
3	111°		105
4	5°		151'
C - D	100°	279°	555'
5	340°		90'
6	(offset)		405'/110'
7 (D)	219°		(intersection)
D - E	165°	344°	452
7 (E)	282°		(intersection)
E - F	192°	12	211
F - G	234°	53°	304
G - A	258'	78°	511'

A   B
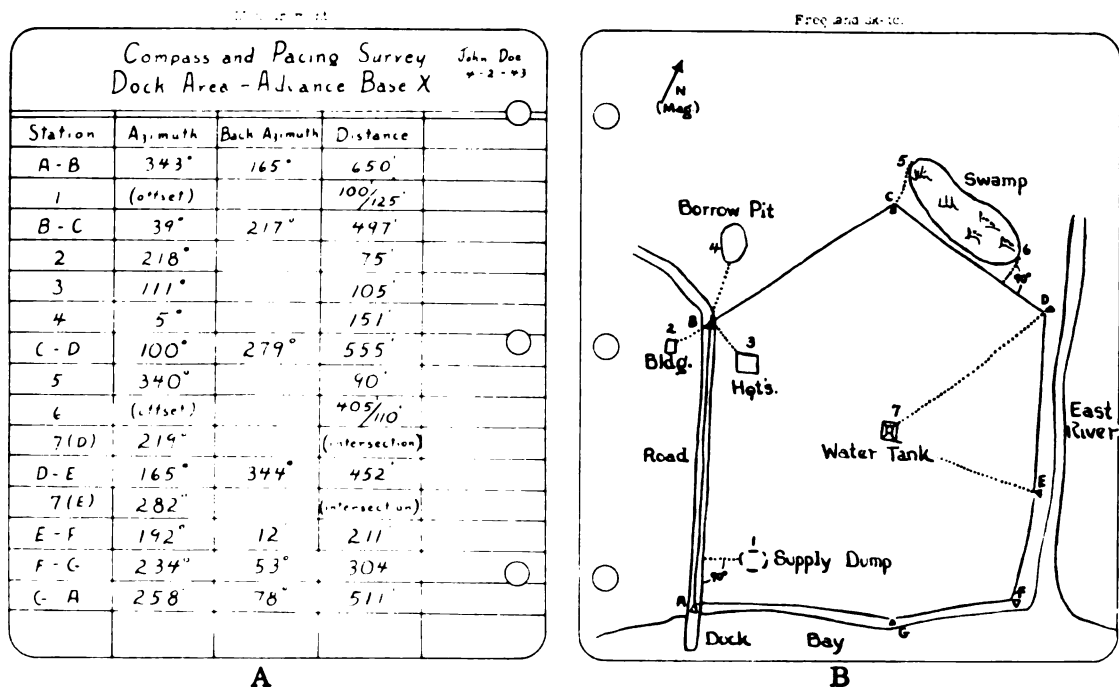
Figure 181.

Notes and freehand sketch of closed traverse survey

    By freehand sketching, a rough map of comparatively small area can be made. The relative positions of various features of the terrain are merely estimated from some high point where vision is unobstructed and the details are sketched in proportionately on a sheet of paper. Maps made by this method are used for preliminary reconnaissance or in areas to be occupied only temporarily.

    The compass and pacing survey is one of the most practical methods of field mapping. Distances are measured by pacing and directions determined by compass readings. The data are recorded as field notes from which the map is plotted on paper. The usual procedure is to run a traverse course which serves as a framework to which the various features of the terrain are tied by offset, radiation, or intersection.

    Fig. 180 represents a closed traverse survey. Starting at point A, the azimuth of the line AB was determined by sighting the line with the compass and the distance AB determined by pacing. The same was done for the lines BC, CD, DE, EF, FG, and GA. The back azimuth of AB was sighted from B, of BC from C, etc., as a check on the azimuth readings. An offset was used to locate point 1. The distance along AB to the point opposite 1 was paced, a 90° angle turned from the traverse line, and then the distance along the right angle to 1 also paced. For points 100 to 200 feet from the traverse line the right angle can be estimated. Point 6 in the figure was located in the same way. Points 2 to 5 each were located by radiation; that is, by taking both the azimuth and the distance from some point on the traverse to the point to be located. Point 7 was located by intersection. The azimuth to 7 was taken from the two known

259
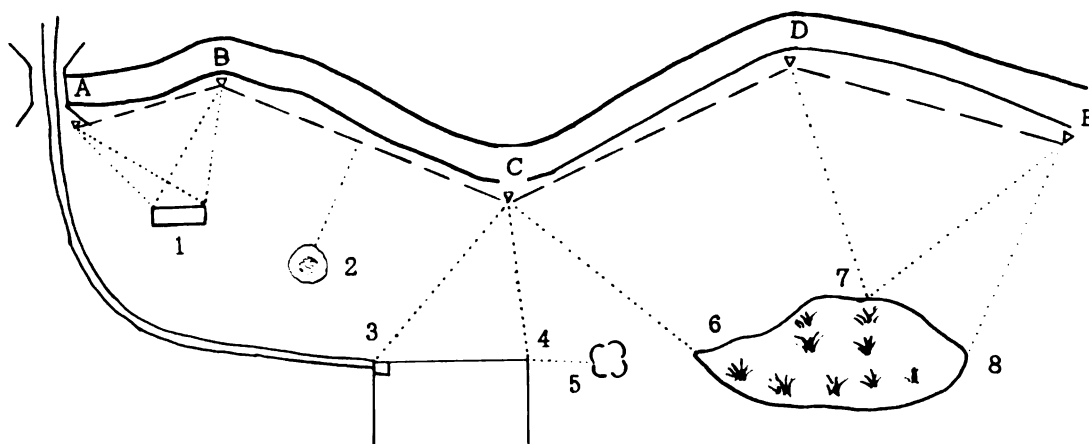
Open survey along a water course.

Point 2 located by offset from traverse line.
Point 5 located by offset from secondary point.
Points 3 4 6 8 located by radiation.
Point 1-7 located by intersection from traverse sections.

Figure 182.
Open traverse survey along a water course
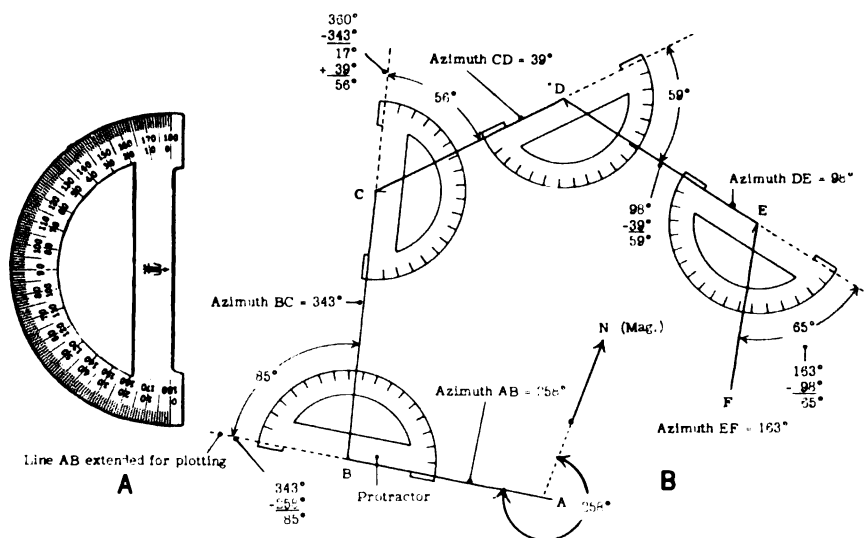
Figure 183.
A. Protractor. B. Method of calculating and plotting angles

260

points <u>D</u> and <u>E</u>. The position of <u>7</u> would be fixed on the plotted map by the intersection of the lines of sight and therefore it would not be necessary to pace the distances to <u>7</u>. An <u>open traverse</u> course does not return to the starting point. Open traverse is used to map water courses, road strips, etc. In areas where visibility is obstructed by jungle, mapping surveys may consist of a series of open traverses along water courses, all joined by cross traverses.

To make a map from the field notes it is first necessary to select a suitable scale. The scale should be large enough so that all the details given in the notes can be shown in proper relationship. Distances are then represented proportionally. Angles are calculated from the azimuths of the lines and are plotted by means of a protractor. In figure 183, for example, in calculating the deflection angle at <u>B</u>, the azimuth of <u>BC</u> (343°) is actually 85° greater than the azimuth of <u>AB</u> (258°). The deflection angle at <u>C</u> is 56°. Since the azimuth of <u>BC</u> is 343°, and therefore 17° west of north, 17° is added to the azimuth of <u>CD</u> (39°), giving a total deflection angle of 56°

When a closed traverse survey is plotted, it will usually be found that the last traverse line will not end on the starting point. This is due to small unavoidable errors in reading the compass and pacing distance. The distance between the end of the final line and the starting point as plotted on the map is called the <u>error of closure.</u> If it is greater than 3 per cent of the traverse course, a gross error has been made and the survey should be repeated.

The sketching board (plane table) survey is a method of mapping in which the data are plotted directly on the paper in the field. Thus the map takes form as the survey progresses. The equipment used consists of the following: A sketching board, a small plane table, 12-1/2 by 15 inches, which attaches to a tripod by means of a locking screw; a triangular scale called an <u>alidade,</u> used for sighting and scaling distances; and a compass.

The procedure in general is the same as in the compass and pacing survey. Distances are measured by pacing, but direction is taken by sighting along the alidade instead of by compass readings.

<u>Figure 184.</u>
A. Mapping with sketching board and alidade. B. Alidade.

Traverse lines are run as shown in Fig. 185 and are as follows:

At point <u>A</u>.

1. Attach the board to the tripod and fasten a sheet of paper to the board by means of thumbtakcs or gummed paper.

2. Set up the board and tripod solidly over Point <u>A</u> (Fig. 185-1). Level the board by eye.

3. Mark a point <u>a</u> on the paper to represent point <u>A</u> on the ground and select a suitable scale.

4. Rotate the board so that the subsequent survey lines will fit on the paper; then lock the board so it will not turn.

5. With the aid of the compass, draw near the edge of the paper a line representing magnetic north. This can be done by placing the compass on the board with the front sight flat on the paper and turning the compass so that the line of sight is on magnetic north. Then draw a line on the paper along the line of the wire of the front sight.

6. Place a pin or pencil point at point <u>a</u> on the paper. Place one edge of the alidade against the pin and sight to point <u>B</u> along the upper edge of the alidade, moving the alidade as necessary about the pin as a pivot.

7. With the alidade held in position, draw a line along the lower edge of the alidade from <u>a</u> toward <u>B</u>.

8. Pick up the board and pace the distance <u>AB</u>.
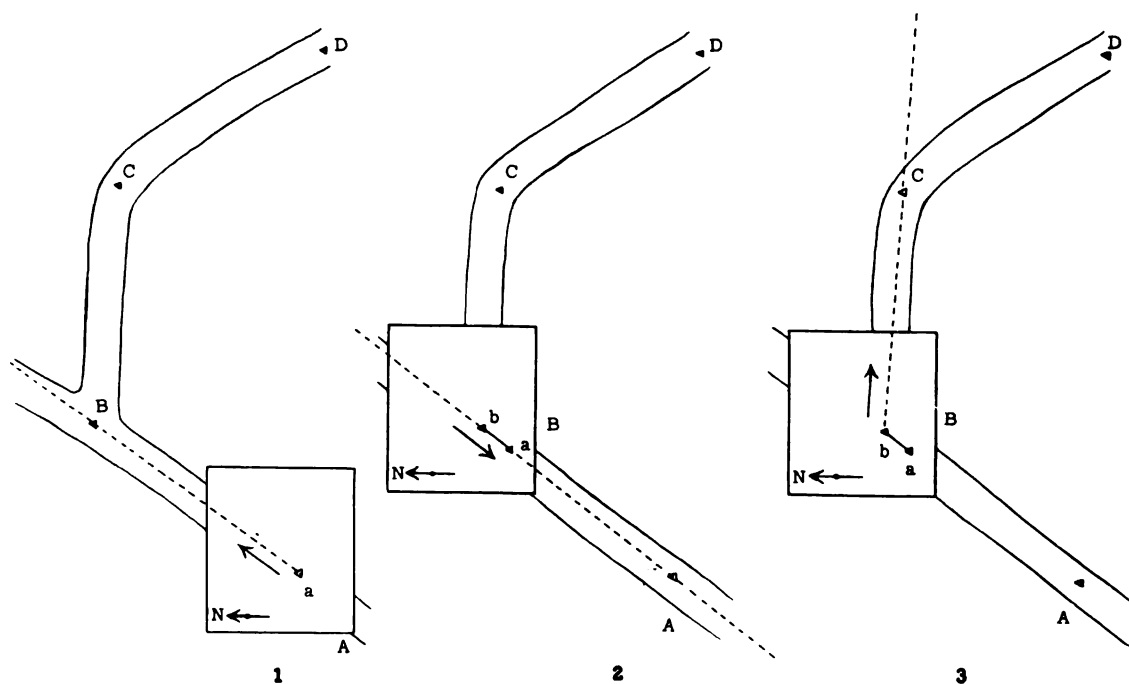
<u>Figure 185.</u>
Plotting traverse line by use of sketching board

262

At point **B**.

1. Set up the board at **B** (Fig. 185-2). Lay off the distance **AB** by means of the scale on the alidade. This will locate point **b** on the map, representing point **B** on the ground.

2. Lay the alidade with its ruling edge along **ab**. Rotate the board so that the line of sight on the sighting edge of the alidade is at **A**. This places the board in the same relative position as it was at **A**. Lock the board so it will not rotate.

3. Proceed as at **A**, sighting **C** to get the direction of the line **bc** to represent **BC** Pace the distance to **C** and scale off **bc** on the board.

Offset and **radiation** are carried out in the same manner as in the compass and pacing survey, except that direction is taken by sighting with the alidade instead of the compass.

Intersection is especially useful in this type of survey for locating points that are visible from two or more traverse points as shown in Fig. 186.

1. The board is set up over traverse point **A**. Point **a** on the paper represents the location of **A** on the ground.

2. Sight and draw in the direction lines toward point **B** and **X**.
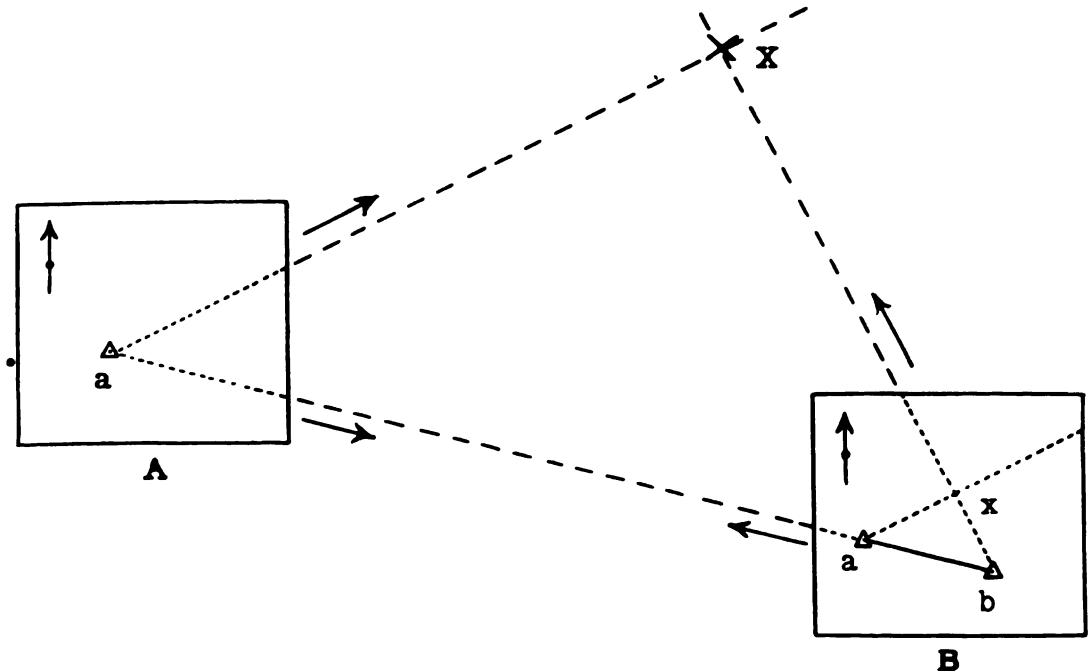
Figure 186.
Locating a point by intersection

263

3. Pace the distance AB, set the board up over B, and scale ab to represent AB.

4. Lay the alidade with its ruling edge along ab and sight back to A by rotating the board. Lock the board when properly oriented.

5. Using the alidade, sight and draw in the line bx. The point at which ax and bx intersect will represent point X.

6. If possible, sight to X from a third traverse point as a check.

Resection: It is sometimes desirable to set the board up at an unmapped point in a previously mapped area to insert additional detail. In case this is necessary, the location of the board may be established by one of the following methods of resection.

1. The compass and two-point method as shown in Fig. 187 A.

    a. The board with the map attached is set up at the unmapped point X.

    b. Orient the board by placing the compass as shown in the figure and rotating the board until the north line on the compass coincides with the north line on the map, then lock the board.

    c. Place a pin at point a, and rotate the alidade about a until the line of sight falls at A. Draw in the line as shown.

    d. Place the pin at b and similarly sight B and draw in the line.

    e. The intersection of the two lines x represents X -- the point on the ground where the board is set up. This is the least accurate of the three methods.

2. The tracing paper method as represented in Fig. 187 B.

    a. Set the board up at X.

    b. Place a clean sheet of tracing paper over the map.

    c. On tracing paper, select any point x to represent X on the ground and draw radiating lines to three visible points, A, B C, previously mapped as shown in Fig. 187 B-1.

    d. Move the tracing paper about over the map (Fig. 187 B -2 and 3) until the direction lines on the tracing paper are directly over points a, b, and c on the map.

    e. Mark point x on the map by pressing the pencil point through x on the tracing paper.

    f. Check by sighting xaA and xbB.

3. The three-point method, involving locating the position of X by a series of approximations, as shown in Fig. 187 C.

a. The board is set up at X, oriented by eye or by compass, and locked.

b. Extensions of lines aA, bB, and cC are sighted and drawn in. In most cases, the lines will not intersect at a point but will form a triangle called the triangle of error (Fig. 187 C-1).

c. Make an estimate (x1) of the correct position of the point. It will be either on the right or left of the triangle and distant from each of the three lines in direct proportion to the distances of the corresponding actual points (A, B, and C) from the occupied point (X).

d. Place the alidade along x1a and rotate the board until the line of sight falls on A.

e. Lock the board and again draw the lines. They will now intersect at a common point or form a second triangle of error smaller than the first one (Fig. 187 C-2).

f. If the lines do not intersect at a common point, make a new estimation (x2) of the location of the point from the second triangle.

g. Reorient the board as in step d and sight and draw in aA, bB, cC as in steps b and e. This time the lines should intersect at a common point (Fig. 187 C-3), giving the true location of x in relation to a, b, and c. This is the most accurate of the three methods of resection but requires more time and care than the other two. However, an experienced man can usually determine the correct point from the first triangle of error.

Aerial photographs are used for many different purposes in military operations. Frequently they will serve as an excellent source for making malaria control maps. When necessary, additional details may be added by means of the surveying methods previously described. Aerial photography has the following advantages over mapping surveys: Maps can be made more quickly from photographs; photographs show a wealth of detail which could not be included in a field survey map; aerial photographs can be made of areas that are not easily accessible from the ground; and areas can be easily rephotographed to keep maps up to date. The disadvantages of aerial photography are: Important features are often obscured by vegetation; important details are not emphasized; the relative position of objects may be inaccurate because of irregularities of line of flight and distortion produced by the lenses of the camera or by the tilt of the camera; and accurate interpretation of details often requires special equipment and trained personnel.
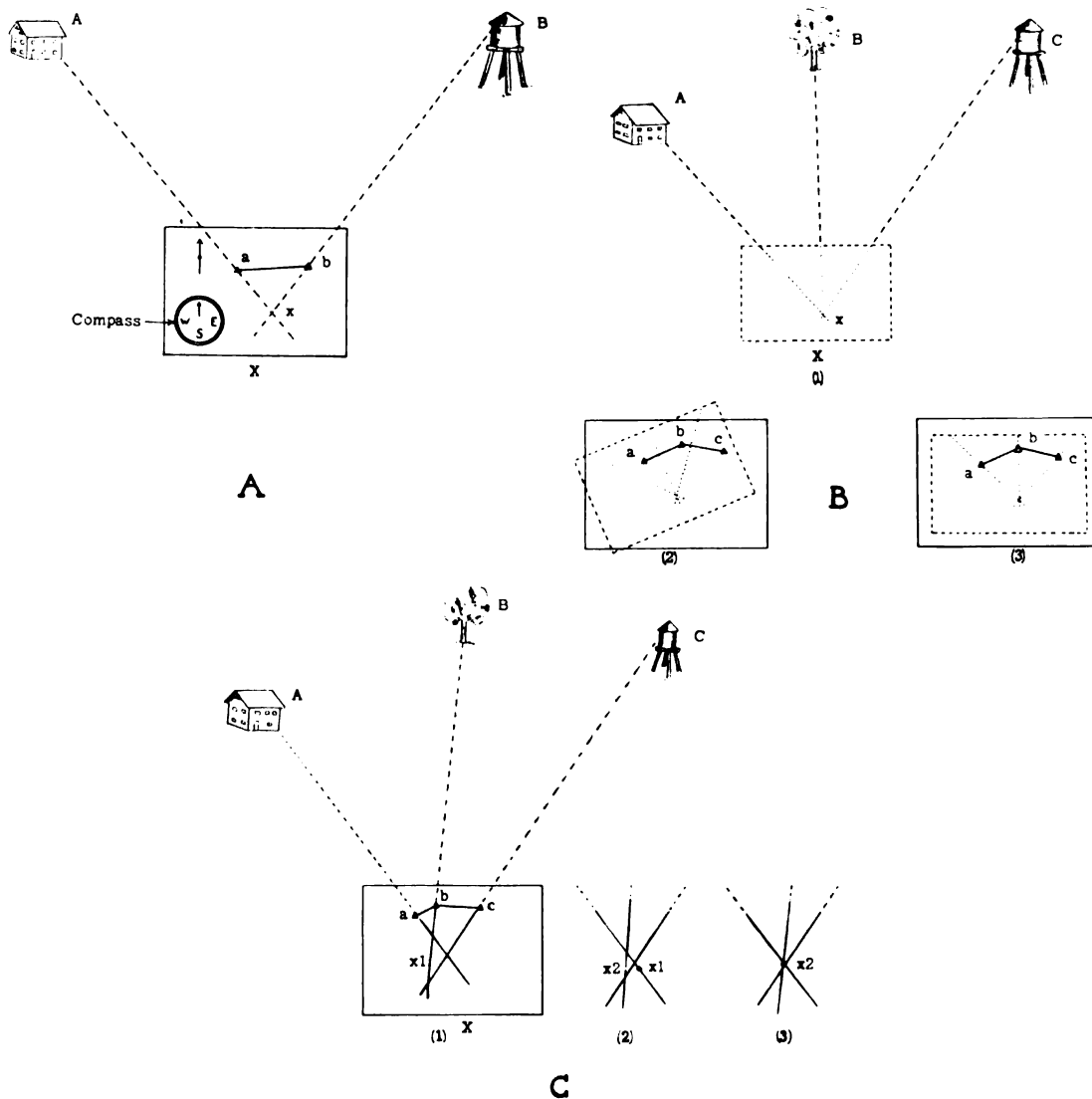
Figure 187.
Locating an unmapped point by resection. A. Compass and two-point method.
B. Tracing paper method. C. Three-point method.

The following are types of aerial photographs: <u>Vertical photographs</u> made with
axis of the camera as nearly vertical as possible; <u>oblique photographs</u> made with the
axis of the camera deliberately tilted from the vertical (of limited value, the parts of
the photograph not being on the same scale); and <u>aerial mosaics</u> made by piecing to-
gether several photographs which have been corrected so that they represent verticals
with the same scale.

<u>Orientation and scale</u> are usually indicated on the margin of the photograph. How-
ever, when not given they can be determined as shown in Fig. 187. The procedure is
as follows: Select two points, <u>A</u> and <u>B</u>, on the terrain that can be easily identified on
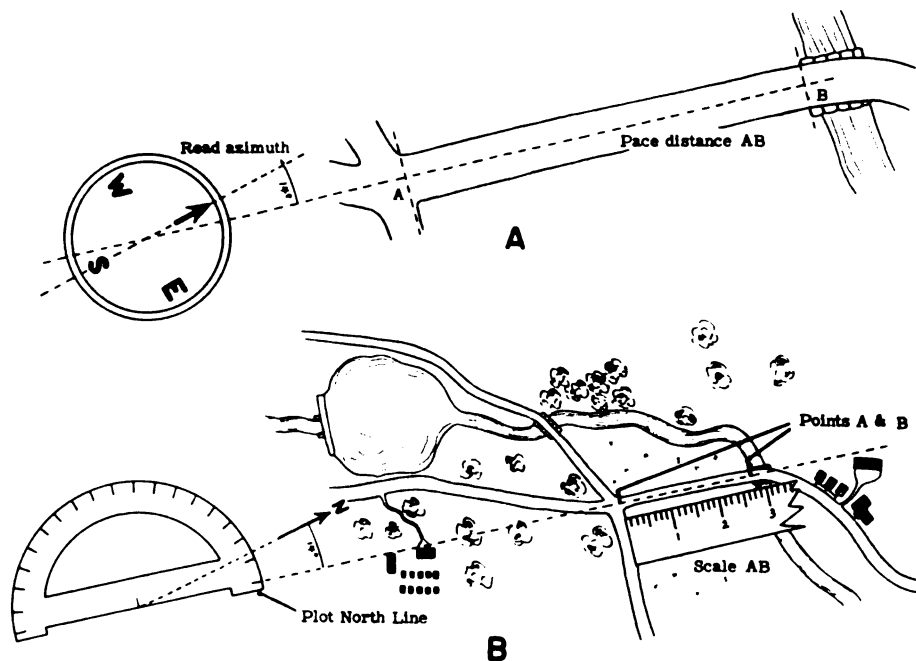
Figure 188.
Establishment of scale and orientation on aerial photograph.
A. Measurements made on ground. B. Plotting and scaling on aerial photograph
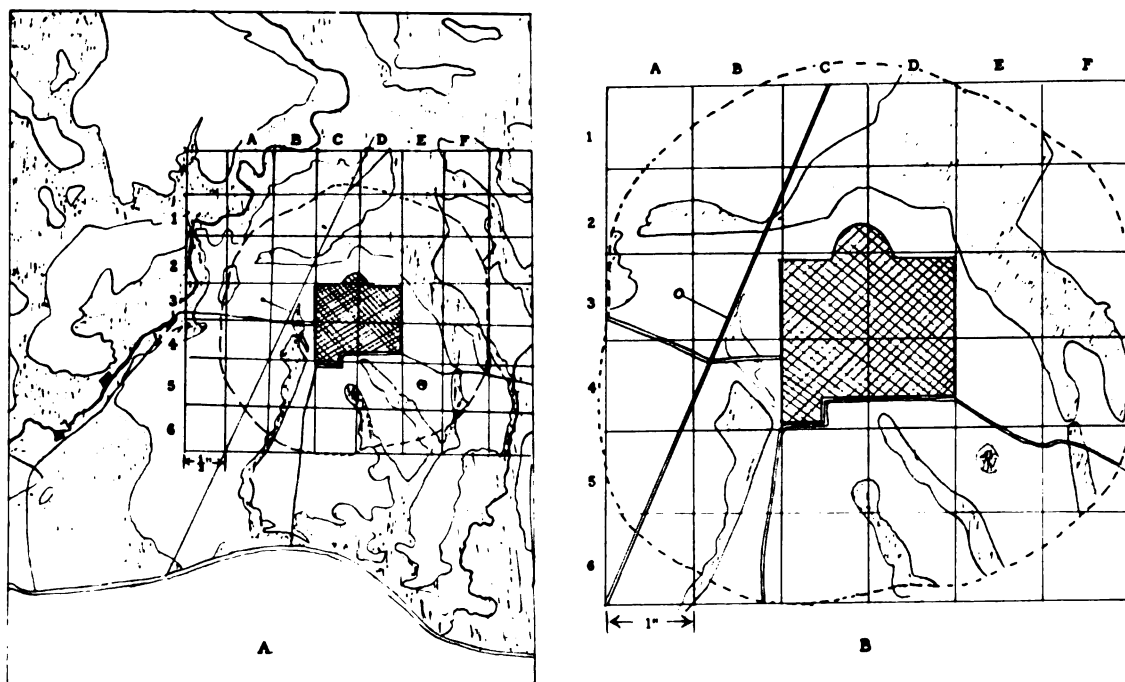
Figure 189.
Grid method of making an enlarged map from a portion of an aerial photograph.
A. Aerial photograph. B. Enlarged map.

267

the photograph; on the line AB on the ground determine the magnetic azimuth by compass and pace the distance; plot the magnetic north line as shown in the figure; measure <u>AB</u> on the photograph; and calculate the scale by the formula:

$$\text{Scale} = \frac{\text{distance AB on ground}}{\text{distance AB on photograph}}$$

If tracing paper (a transparent drafting paper) is available, a map may be made from an aerial photograph by tracing off the desired details. If tracing paper is not available or if it is necessary for the map to be larger or smaller than the photograph, a reproduction may be made as shown in Fig. 189. The procedure is as follows: Rule off a grid of 1- or 1/2-inch squares on the photograph; number the columns of squares and letter the rows. On a clean sheet of paper rule off a grid in which the sides of the squares are larger or smaller by the proportion which the scale is to be increased or decreased. For example, if the scale of the photograph is 1 inch equals 1,000 feet, and the squares on the photograph are 1 inch on a side, then to make a map having a scale of 2 inches equals 1,000 feet (1 inch equals 500 feet), make the squares on the paper 2 inches on a side. Number and letter the squares on the paper to correspond with those on the photograph. In each square on the paper draw, in the same relative position, the detail that is in the corresponding square on the photograph.
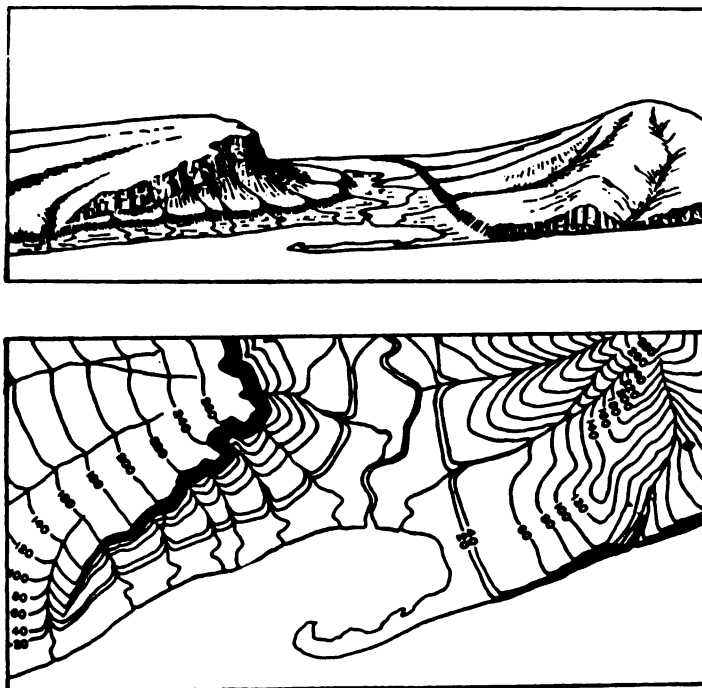
Figure 190.
Map showing contour lines obtained from actual ground elevations

268

Existing maps of various types can be used as the basis for making a malaria control map. Maps with contour lines are especially useful. A contour line joins points having the same elevation. A clearer conception of a contour line may be had by imagining a valley partly filled with water to an elevation of 50 feet. The shore line of the lake will then be the 50-foot contour. If the level of the water is raised 5 feet, the new shore line will be the 55-foot contour, and so on. Contour lines may be spaced to show increases in height of 5 feet, 10 feet, and up to 500 feet. This spacing in regard to height is called the contour interval. Contour lines have the following characteristics: All points on any one contour line have the same elevation; every contour line closes on itself either within or beyond the limits of the map; contour lines can never cross each other except in the case of an overhanging cliff; they are close together when the ground is steep and far apart on gentle slopes; and they run up a valley, across the stream, and back the other side.

Leveling

In a level survey, vertical distances are measured to determine the comparative elevations of different points. Two types of level surveys are used in malaria control, profile surveys and cross-section surveys. In cross-section surveys, the volume of earth work is estimated. They are necessary only on large projects and should be under the direction of an experienced person. For further information, see any training manual or test on surveying.

In profile surveys, comparative ground elevations are established to determine the location and grade of drainage ditches. For ditches that are to be less than 400 feet long and on a good slope, the profiles may be made with chalk line and line level. The procedure is as follows:

1. Stakes are set up at 25-foot intervals on the center line of the proposed ditch.

2. A chalk line is run from post to post. Care must be exercised to pull the line tight to remove any sag and to have the line as nearly level as possible. The line level should be reversed frequently to check.

Reverse level to check.

|←—— 25' ——→|←—— 25' ——→|←—— 25' ——→|
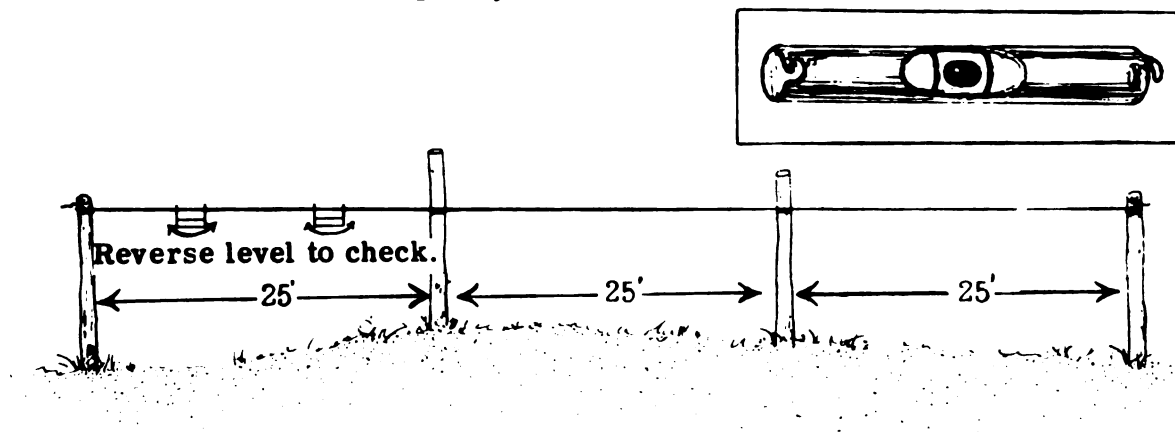
Figure 191.
Setting up chalk line for profile survey
269

3. Assign an assumed (arbitrary) elevation of 100.0 feet to the lowest point (outfall) and measure up to the chalk line to establish its comparative elevation.

4. Measure from the chalk line to the ground to determine the comparative ground elevations. These measurements should be made at the 25-foot intervals and at any intermediate points where there is a perceptible change in slope.

Measurements are recorded in note form as shown in the figure. When elevations are plotted to scale, the position of the ditch bottom can be determined and drawn in. The depth of the ditch at any point can then be obtained from the plotted profile.
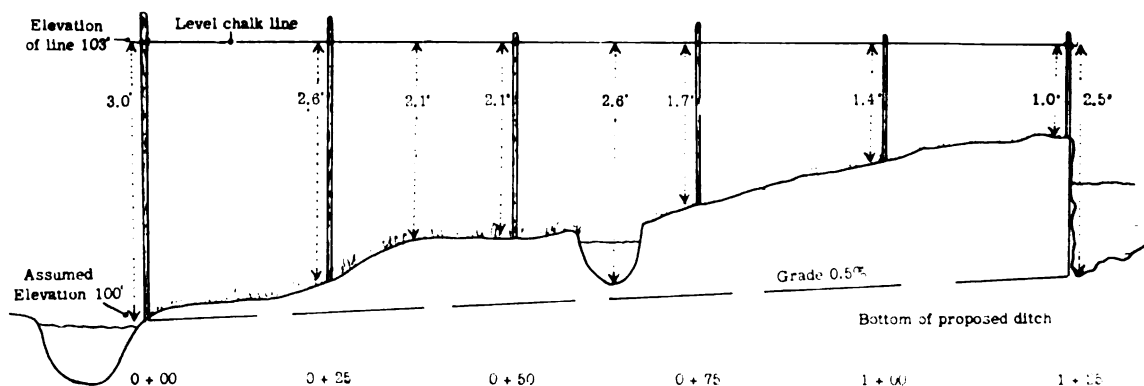
Figure 192.
Diagram of profile survey by means of chalk line, vertical proportion exaggerated to emphasize differences in elevation.

In making a profile survey of longer ditches, especially on flat land, an engineer's level and level rod should be used. The engineer's level consists of a telescope and spirit level supported on a base by a column and four leveling screws. The instrument is mounted on a wooden tripod when in use and so adjusted that the line of sight through the cross hairs in the telescope is horizontal. This is a precision instrument. It should not be bumped or jarred, and the leveling screws should never be made so tight that they will not turn easily by hand. The leveling rod is made of wood and has the face graduated in tenths and hundredths of a foot.

The following terms are used in profile surveys made with an instrument:

1. Bench mark (BM) -- a permanent or semipermanent reference point having a known elevation. In drainage work, semipermanent bench marks are frequently made by driving a long stake or pipe into the ground, leaving about 8 inches above ground level. The elevation point is the top of the stake or pipe. This elevation may be the distance above sea level or above some other reference point. When no reference point is available, the bench mark may be assigned an assumed elevation, usually 100.00 feet. For profile surveys with an engineer's level, bench mark elevations are usually measured to the nearest 0.01 foot.

270

2. <u>Turning point</u> (tp) -- a temporary bench mark used as a reference elevation when it is necessary to change the location of the instrument. It is usually a short stake driven into the ground.

3. <u>Height of instrument</u> (HI) -- elevation of the line of sight of the instrument (Fig. 194 B).

4. <u>Plus sight</u> (+s) -- a measurement on the rod from a known elevation (BM or tp) to establish the elevation of the line of sight of the instrument. (Elevation of BM or tp) plus (+s) equals HI. Do not confuse with a "plus" in chaining.

5. <u>Minus sight</u> (-s) -- a measurement on the rod from a known elevation (HI) to establish the elevation of a point on the ground or of a new BM or tp. (HI) minus (-s) equals elevation.
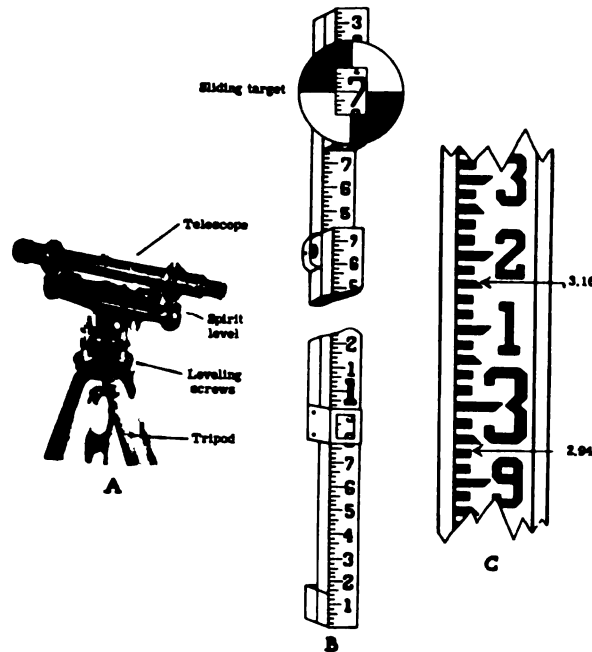
<u>Figure 193.</u>
Engineer's level and leveling rod

The procedure in making a profile survey by means of an engineer's level is shown in Fig. 194. The steps are as follows:

1. The proposed ditch line is chained out, stakes being set at each station and at pluses wherever there is a perceptible change in the slope.

2. A bench mark is set near the beinning point but far enough away from the ditch line so that it will not be disturbed by any future construction work. In the example given, an assumed elevation of 100.00 feet is assigned to this bench mark and it is designated as Bm 1.

271

Figure 194.

A. Map of proposed drainage ditch. B. Diagram of provile survey
for proposed drainage ditch. C. Plotted profile with grade drawn in.

3. Assuming the optical range of the instrument used as about 500 feet, the level
is set up at approximately the points shown in figure 194 B. It is usually desirable to
set it up a few feet to the right or left of the center line. The telescope is adjust-
ed with the leveling screws so that the level bubble remains centered when the instru-
ment is revolved.

4. A rod reading is taken on BM 1 to determine the HI. This is a plus sight; the
elevation of the line of sight of the instrument is now fixed at 100.00 feet (BM eleva-
tion) plus the rod reading.

5. Rod readings are now taken at all stations and pluses starting at 0+00 and
progressing to 9+00. The rod is held on the ground beside the stake, not on top of the
stake, because these readings are taken to determine the actual ground elevations.
These are minus sights because they are measurements from the known elevation of
the line of sight to an unknown elevation on the ground. Ground elevations are taken to
the nearest 0.1 foot.

6. Assuming that the range of visibility of the instrument is limited to 500 feet,
it will now be necessary to move the instrument. A turning point (tp 1) is therefore
set in the vicinity of 9+00 and a rod reading taken on it to determine its elevation.
This reading is also a minus sight.

272

7. The instrument is now moved to about half the remaining distance, set up as before, and a second reading taken on tp 1. This is a plus sight to determine the elevation of the new line of sight from the known elevation of tp 1.

8. Rod readings are now taken on the ground at each of the remaining stakes on the proposed ditch line. These are all minus sights.

9. At the end of the line a second bench mark (BM 2) is set, and a minus sight taken to determine the elevation of BM 2 in relation to BM 1.

A level survey must always be run back to the starting bench mark as a <u>check</u> against error. The procedure is as follows:

1. Change the HI at the last set-up by relocating the instrument or by forcing the legs of the tripod a little farther into the ground. Relevel the instrument.

2. Take a reading on BM 2 (a plus sight) to determine the new HI.

3. Set tp 2 somewhere in the vicinity of 9+00 and take a rod reading to determine its elevation. This will be a minus sight. (If it can be found easily, tp 1 may be used.)

4. Move the instrument to a point approximately half way between tp 2 and BM 1 and level up for sighting.

5. Take a second rod reading on tp 2 to determine the elevation of the new line of sight (HI). This will be a plus reading.

6. Take a reading on BM 1 (a minus sight) and calculate the elevations.

In the field notes, Fig. 195, the difference between the assumed elevation of BM 1 and the elevation found in checking is 0.03 feet. This shows that no gross error has been made at the turning points or at BM 2. If the error exceeds 0.15 feet, the survey should be repeated. Note that only those errors in the framework (bench mark, turning points, and elevations of line of sight) will appear in the check. Since no ground elevations are taken in the check, any errors at those individual points will not be evident. If the framework is correct, however, any gross error in a ground elevation will be apparent when the profile is plotted.

After the field work is completed, a profile is plotted from the field notes as shown in Fig. 194 B. In order to emphasize small differences in elevation, a much larger scale is used for vertical distances than for horizontal distances. The most common scales are horizontal -- 1 inch equals 100 feet, vertical -- 1 inch equals 1 foot, or 1 inch equals 2 feet. When the profile is completed, the grade line (bottom) of the proposed ditch can be drawn in to fit the ground elevations. However, the type of soil, volume of water to be carried, location of tributary ditches, and so on, must be considered in deciding on the best position of the grade line. A cut sheet (table of

273

ditch depth) can now be prepared by scaling on the profile the distance from the grade line to the surface of the ground (Fig. 194 C.)

To transfer the cut sheet data to the ground, either **batter boards** or T's are used as shown in Fig. 196. When batter boards are used, the tops of all the boards are set the same distance above the proposed grade. Thus the string connecting the boards will make a line parallel to the grade line and can be used as a base for measuring down to grade at any point. When the T's are used, the upper edges of all the cross pieces are set the same distance above grade (bottom of the proposed ditch), and the line of sight between the upper edges of the cross pieces serves the same purpose as the string line on the batter boards. The T's are less accurate than the batter boards but are more quickly set up.

Profile Proposed Ditch on Blue River

Station	+ S	H I	- S	Elev.	
BM₁	4 89	104 89		100 00	(Assumed)
0 + 00			9 3	95.6	
0 + 35			6 1	98 8	
1 + 00			5 0	99 9	
2 + 00			4 7	100 2	
3 + 00			4 8	100 1	
4 + 00			4 9	100.0	
5 + 00			5 2	99 7	
6 + 00			5 5	99 4	
6 + 29			5 6	99 3	
7 + 00			6 5	98 4	
7 + 59			7 1	97 8	
8 + 00			6 9	98 0	
9 + 00			5 3	99 6	
tp₁			4 92	99 97	
	3 79	103 76			
10 + 00			4 0	99 8	
11 + 00			4 0	99 8	
12 + 00			4 2	99 6	
13 + 00			4 0	99 8	
13 + 57			4 4	99 4	
14 + 00			4 6	99 2	
14 + 32			4 8	99 0	
15 + 00			4 6	99 2	
15 + 62			4 4	99 4	
16 + 00			4 2	99 6	
16 + 31			3 8	100 0	
17 + 00			2 0	101.8	
BM₂			0 35	103 41	
Check					
BM₂	0 31	103 72		103 41	
tp₂			4 10	99 62	
	4 91	104 53			
BM₁			4 56	99 97	(Elev. 100 0 assumed)
			Error	+ 0 03	

Figure 195.
Field notes of profile survey
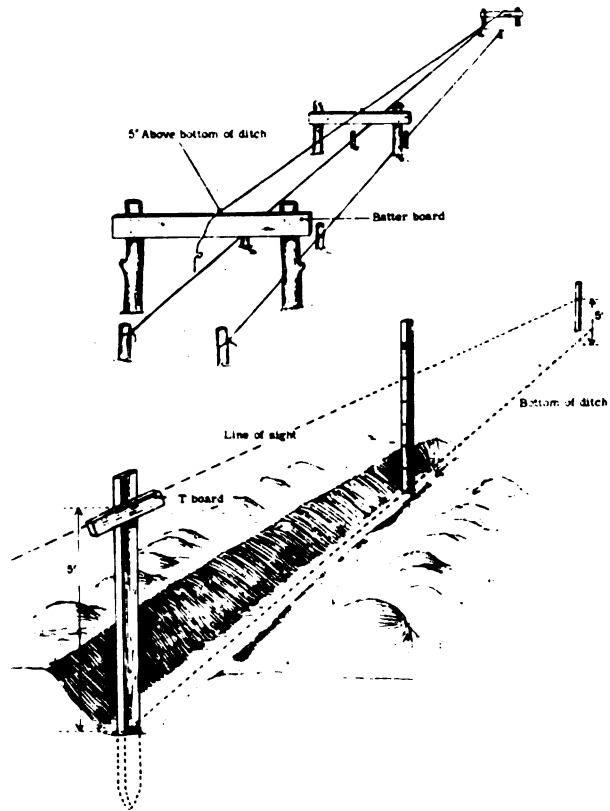
Figure 196.
Use of batter and T-boards to determine the grade line of a ditch

Bates, Marsten. The Natural History of Mosquitoes. Macmillan Co., N.Y., 1949. 379 pp. An easy-to-read discussion of mosquito biology, bionomics, relation to disease, and field study techniques.

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Various Authors. Insect Control Training Manual. U.S. Department of Health, Education and Welfare, Public Health Service, Communicable Disease Center, Training Branch, Atlanta, Georgia. Preliminary issue, 13 chapters. 1954-1957. A compilation on arthropod morphology, biology, bionomics, relation to man, and survey and control methods.

SECTION IV

ENTOMOLOGICAL TECHNICS

ENTOMOLOGICAL TECHNICS

A. COLLECTION AND PRESERVATION OF ARTHROPODS

Since the specific identification of medically important arthropods is often very helpful or even essential in determining which measures should be used in their control, methods of collecting and preparing such specimens are included here. Because of the enormous numbers of species, exact identification can best be made by a specialist highly trained in the taxonomy of a particular group of arthropods. If specimens are collected which seem to be of medical importance, a tentative classification can be made by using the keys and figures in this manual. For more detailed and accurate identification, specimens should be sent to the Commanding Officer, U.S. Naval Medical School, Bethesda 14, Maryland.

Directions for collecting, preparing, and shipping such materials are outlined in this section. Do not send living specimens through the mails. In shipping specimens mounted on slides or contained in vials of alcohol, special care must be taken in packing to prevent breakage. In the tropics particular care should be taken to store insects in dry containers. Mold and insect pests will soon destroy a collection if it is not properly cared for. Ointment tins or pill boxes containing specimes should be enclosed in mailing tubes or other sturdy containers for shipping. If pinned adults are sent, the pins must be forced firmly into place and the mounting box must be enclosed in excelsior within another sturdy shipping box and plainly labeled "Fragile." All shipped material, should be accompanied by complete data as to locality, date, elevation, collector's name, and other pertinent information as to habits, habitat, abundance, and distribution. As far as possible, reared specimens should be accompanied by associated larval and pupal skins.

Equipment and Methods

The information given here does not apply specifically to the collection of insects of medical importance, but to the collection of arthropods in general. The Orders covered in this manual such as Coleoptera, Lepidoptera, and Hymenoptera may be of sufficient interest to warrant the brief promulgation of standard methods of collection and preservation.

The equipment required for arthropod collecting is made up of a few simple items such as killing bottles, nets, suction bottles, small camel's hair brushes, relaxing jars, spreading boards, folded papers or envelopes for Lepidopterous adults, scissors, forceps, small cardboard boxes containing cellucotton, vials, insect pins and Schmitt boxes.

Killing bottles: The killing bottle should be of fairly heavy glass, with a wide mouth, and of several different sizes. Small ones may be made of heavy, pyrex test tubes. The killing agent is usually calcium, potassium, or sodium cyanide. The granular or flake cyanide in a cloth bag or nested in cellucotton is placed in the bottom of the container (a heaping teaspoonful of cyanide is required for a 1 to 1-1/2 inch test tube, while a greater amount is necessary for larger bottles). The cyanide is then covered with a cellucotton plug consisting of several layers, or with about 1/4 inch of dry sawdust. In bottles greater than 1-1/2 inches in diameter a thick mixture of freshly prepared plaster of Paris and water is then poured over the material to a depth of one-fourth inch. The plaster of Paris is allowed to harden for a few hours, in the open air where it is safe from children and pets. From this time on, the killing bottle is kept tightly closed. The small bottles can be prepared with several snugly-fitting disks of blotting paper instead of the plaster of Paris. Care must be taken how-ever, to insure that the disks are tight enough to keep the cyanide from falling out. All such bottles and test tubes must always be labeled conspicuously "POISON," kept away from children, people who do not realize the poisonous nature of the chemical, and animals. Cyanide is a deadly poison, and must be handled very carefully. Tape the bottoms of the killing bottles to prevent scattering of the contents if they are acci-dentally broken. Never test the action of a killing bottle by smelling the gas. The bottles should contain strips of toilet tissue to absorb the moisture and keep the insects from rubbing together (Fig. 197 A & B). The paper strips should be burned and re-placed as they become moist, and the insides of the bottles should be kept wiped dry. The cyanide from old deteriorated bottles should be burned or deeply buried.
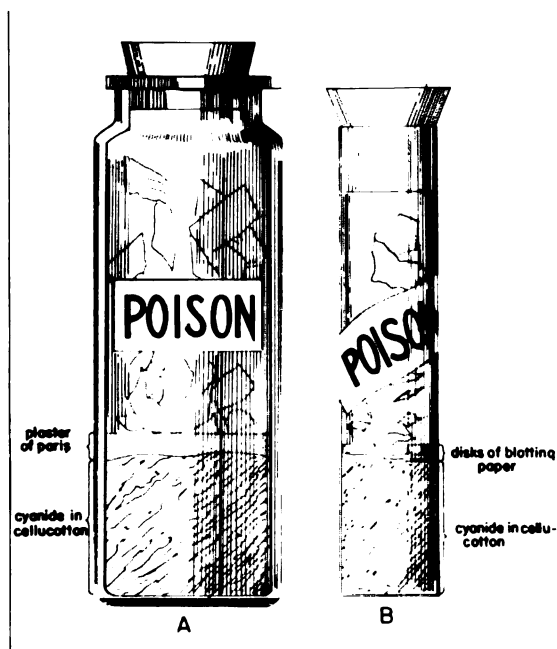
Figure 197.
Killing bottles. (A) large, wide-mouth cyanide bottle for large insects; (B) vial-type cyanide bottle for small insects (after Oman).

An ethyl acetate (acetic ether) killing bottle is prepared by pouring a half-inch layer of plaster of Paris into a bottle or vial, and allowing it to harden. The plaster of Paris is then dried completely in an oven, saturated with ethyl acetate and the excess fluid poured off. This type of killing bottle will last for months, if kept tightly corked. It has the advantage that when it no longer kills, it may be again dried in an oven and recharged.

A killing bottle that is comparatively slow in action may be quickly prepared by placing 3 or 4 ammonium carbonated cubes in a bottle, covering them with a platform of perforated cardboard, and closing with a tightly fitting stopper. Such a killing bottle is quite safe, and leaves the insects in a relaxed state for pinning.

279

Many arthropods should be placed in 70-75 per cent ethyl alcohol or other liquid preservative instead of a killing bottle. Alcohol should be used for killing ants, aphids, beetles, mayflies, silverfish, termites, springtails, lice, fleas, certain soft-bodied bugs, centipiedes, millipedes, ticks, spiders and mites. Insect larvae are killed in boiling water, then placed in alcohol. Small arthropods should be mounted on slides; hard-bodied insects may be removed from alcohol, dehydrated with 100 per cent alcohol, degreased in xylol or benzol, dried and mounted on pins.

Specimens with a great deal of fatty tissue that have been killed with cyanide or ethyl acetate should be soaked in a bath of commercial sulfuric ether from a day to a week. The soaking should continue until the dissolved oils stop yellowing the fluid. Absorbent material, such as filter paper, should be placed in the bottom of the bath to take up the waste. Ether must be very carefully used because of its extreme inflammability. Chloroform, benzene, xylene, or diethyl carbonate are other solvents that may be used.

Insect Nets: The necessary parts of an insect net are the cloth bag, and a loop or ring attached to a handle. The handle has a groove cut vertically along each side of the end nearest the net, to receive the wires from the loop. The ends of the wires are bent inward at right angles and enter the wood at holes bored at the end of the grooves. They are held in place by wire binding. The loop should be 12 to 15 inches in diameter, and made of 3/8 inch rigid steel wire, preferably piano wire (Fig. 198). The net bag may be made of silk bolting cloth of various sized meshes, or of nylon, but the beating, or sweep net should be made of 6-ounce drill, light canvas or heavy muslin. The length of the bag should be about twice the diameter of the ring, and made of four sections cut as in Fig. 199. When sewn together the four pieces form a cone-shaped sack. A narrow strip of muslin should be sewed around the open end of the cone to bind it to the wire ring. This may be made in the form of a sleeve which can be slipped over the wire before it is fastened to the handle. Two nets should be available, one of light netting for Leipdoptera, and a sturdy one for sweeping vegetation. A third net with a short bag 3 to 9 inches long made of sturdy fine mesh netting or copper wire,
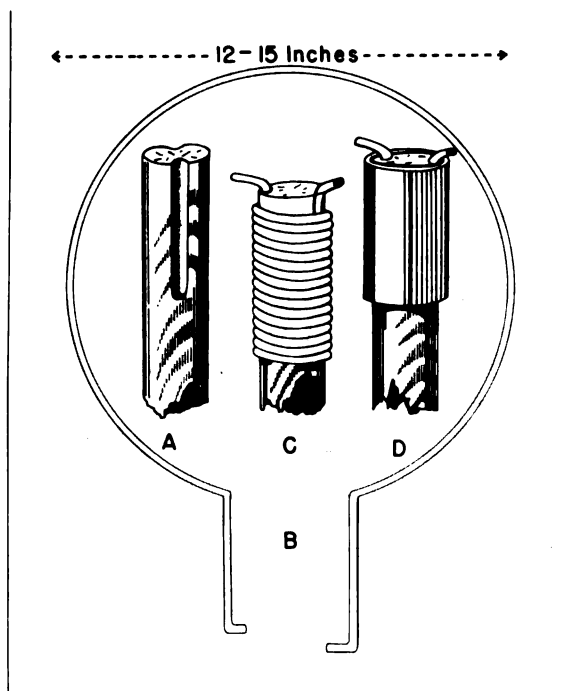
Figure 198.
The Net. Grooves in handle (A) end in holes through handle which receive hooks of ring arms (B). Ring may be bound to handle by wire (C) or a moveable joint may be effected with a metal ferrule which slides (D). (After Ross.)

280

should be used for aquatic insects. In this type the net opening should be either square with the handle at one corner, or semicircular with a straight side opposite the handle. The bag should be fastened to the wire by a canvas band.
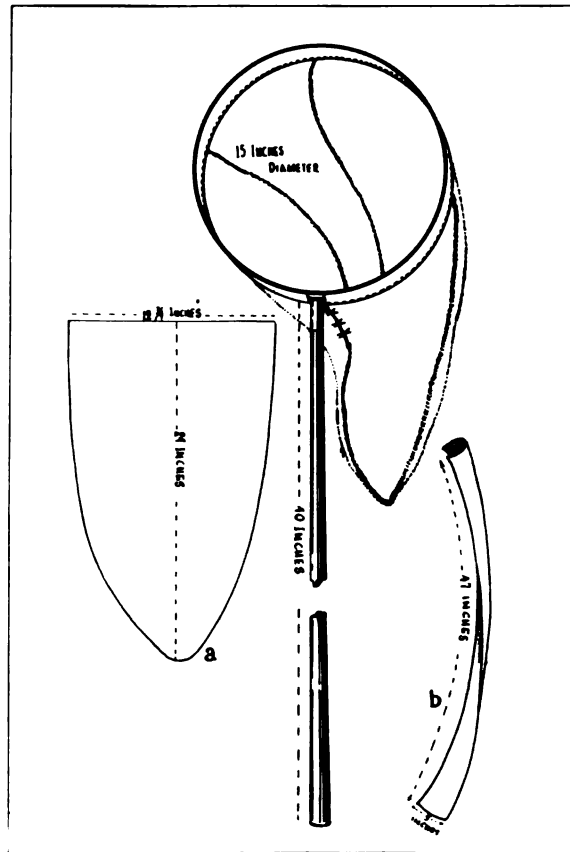
Figure 199.
The bag. The bag is cut from four pieces
shaped as in (a), and the circular opening
at the top of the bag is bound with a narrow
strip of stout muslin or light canvas (b),
by means of which the bag is attached to
the ring. (After Ross.)

Suction Devices: For removing small insects from a net, or catching those resting on stones or other objects, suction tubes similar to those utilized in collecting mosquitoes may be used, except that the pick-up tube is ten inches long, enters the cork without the rubber tubing, and is not flexible (Fig.203 (c)). A glass vial 1 to 1-1/2 inch in diameter and about 4-1/2 inches long, closed by a rubber stopper containing two holes for the plastic tubing, is required.

281

Separators: Arthropods that live in ground litter may be collected by a Berlese funnel. The leaf mold or litter is placed in a sieve over a funnel which leads to a container of liquid preservative. The small arthropods are driven out of the material in the sieve by the drying effect of a light bulb or other heat source and fall into the preservative. The heat source may be replaced by a repellent such as naphthalene or paradichlorobenzene. In this case a tightly fitting wooden cap treated on the under-side with melted repellent, is placed over the funnel to drive the arthropods out of the material in the sieve.

Attraction of Lights and Baits: Insects may be collected at light or in light traps. It is often possible to obtain insects by this method that are not obtainable by any other. Blue lights attract more insects than other colors.

Sugar, syrup, or fermented baits are also used for collecting moths, ants, and many other insects by painting the material on trees or posts. They may also be captured by baiting simple jar traps with sweets, decaying meat, or fermenting materials. The jar is buried with the open end flush with the surface of the ground.

The Relaxing Jar: Relaxing jars are wide-mouthed containers containing one or two inches of clean sand saturated with a water-phenol (carbolic acid) solution (a few drops of phenol to the amount of water needed to saturate the sand). This prevents mold from growing in the jar. A piece of cork is then laid on top of the sand. The dry insects are placed on the cork, and the lid to the jar replaced as nearly air-tight as possible. It requires from one to three days to relax insects.

The Spreading Board: This is used for large-winged insects and is made of a hard wood base 1/4 by 4 by 12 inches, two end pieces 1/2 by 3/4 by 4 inches, two softwood top pieces 1/2 by 1-7/8 by 12 inches and two pieces of flat cork 3/16 by 11 by 1 inches.
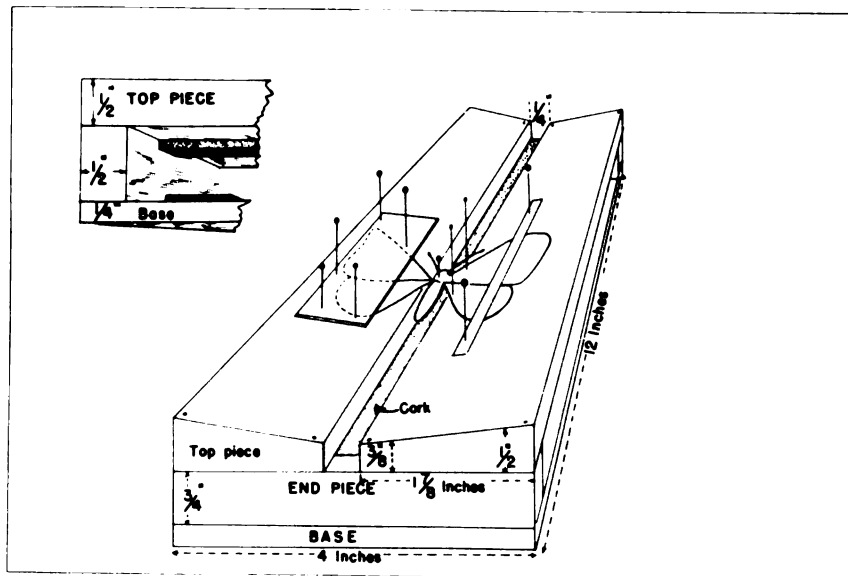
Figure 200.

Spreading Board for Lepidoptera and Odonata. The wings
are drawn forward and pinned temporarily as shown on
right. Left – completed.

The top pieces are planed at an angle with the outer edges 1/2 inch thick and the
inner edges 3/8 inch thick. The inner edges are mounted 1/4 inch apart. One of the
cork strips is glued beneath the tops across the 1/4 inch opening, the other to the
upper side of the base directly beneath the first piece of cork. Freshly caught or
thoroughly relaxed insects are spread on the board as shown in Fig. 200. The insect
is first pinned to the cork below the opening between the top boards. Strips of paper
are held down over the wings while they are pulled forward to the proper angles with
the point of an insect pin placed below the wing vein. The rear margin of the fore
wing must be at right angles to the insect's body. The front margin of the hind wing
lies just under the rear margin of the fore wing as shown. The pins are placed
through the paper which is pulled taut over the wings. No pins pass through the wings.
The abdomen, head and antennae are also held in proper position by pins.

Pinned Specimens: The hard-bodied insects will retain their shape when pinned
in a box. Pins are furnished in various sizes, the numbers 2, 3 and 4 being the most
satisfactory for normal purposes. The larger bodied insects are pinned vertically
through the body. Standard methods of pinning should be used (Fig. 201).

283

1. <u>Hymenoptera and Diptera</u> (Bees, wasps, and flies): Pin through the thorax between the attachment of the fore wings, to the right of the middle line (Fig. 201 D).

2. <u>Orthoptera</u> (Grasshoppers, etc.): Pin through the rear portion of the thorax to the right of the middle line (Fig. 201 A, B.)

3. <u>Hemiptera</u> (Reduviids, etc.): Pin through the scutellum to the right of the middle line (Fig. 201C).

4. <u>Coleoptera</u> (Beetles): Pin through right wing cover near middle line and base of wing (Fig. 201 E).

5. <u>Lepidoptera</u> (Moths and butterflies): Odonata (dragon flies and damsel flies): Pin through the thorax in the center between the attachments of the fore wings (Fig. 201 F, G).
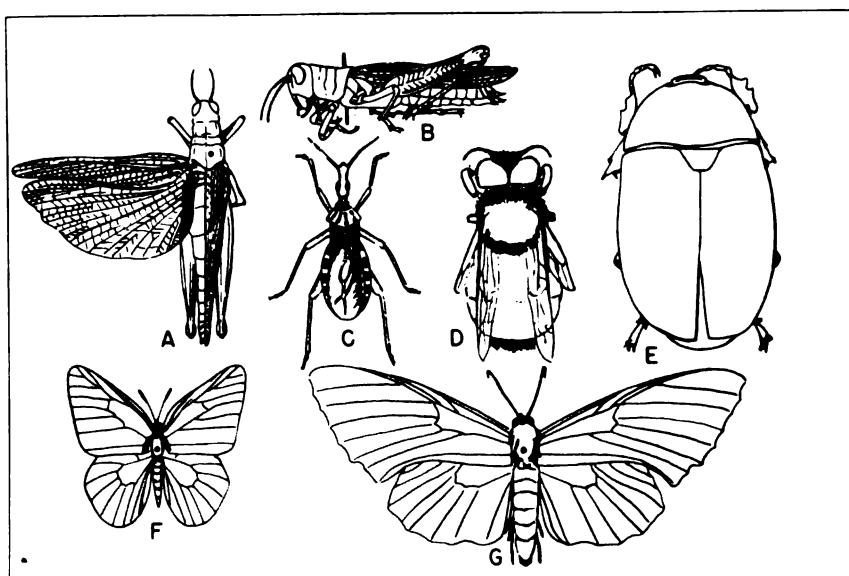
Figure 201.
Examples of correct pinning methods for common insects;
the black spots indicate location of pins. (After Oman.)

The legs, wings and antennae should be arranged in the proper position for viewing while the insect is still fresh or relaxed. The specimen should be at a uniform height on the pin, just low enough that the pin may be grasped without touching the specimen with the fingers. Supply houses furnish pinning blocks for positioning the insects and labels on pins.

Smaller insects that do not lend themselves to pinning through the body may be mounted on card points. The pin is placed through the large end of the card, and the specimen glued to the point (Fig. 204 B). "Minuten nadeln" pins are also used to mount small insects (Fig. 204A).

284

Labeling Specimens: All specimens caught must have a temporary label placed with them, recording essential information regarding date and place of collection. The permanent label will be pinned below the specimen or placed in the vial in the preservative. Additional data associated with the specimen by lot number should be kept in a notebook. The essential information is: (1) location (place of collection), (2) date (day, month and year of collection), (3) collector's name, (4) host (animal or food plant, material attacked, or where resting when captured), (5) lot number, corresponding with notes.

The ink utilized in making labels must be permanent India ink, so that it will not run in the liquid preservative. Labels printed with small type are much better than those printed with ink. Supply houses furnish partially printed labels. The labels on pins should be placed under the specimen with the longest sides parallel with the sides of the specimen, and the left margin toward the head end of the insect.

Housing the Collection: The care of the collection is very important. Standard Schmitt boxes are highly recommended for pinned specimens and are obtainable from supply houses (Fig. 202). These boxes are considered to be nearly pest proof. Specimens in preservative need no upkeep except to replace the liquid as it evaporates.

A small amount of naphthalene or paradichlorobenzene should be placed in the boxes, within a small box with perforated top or in cloth bags. Moth balls may be mounted on pins by heating the head of the pin and inserting it in the ball.
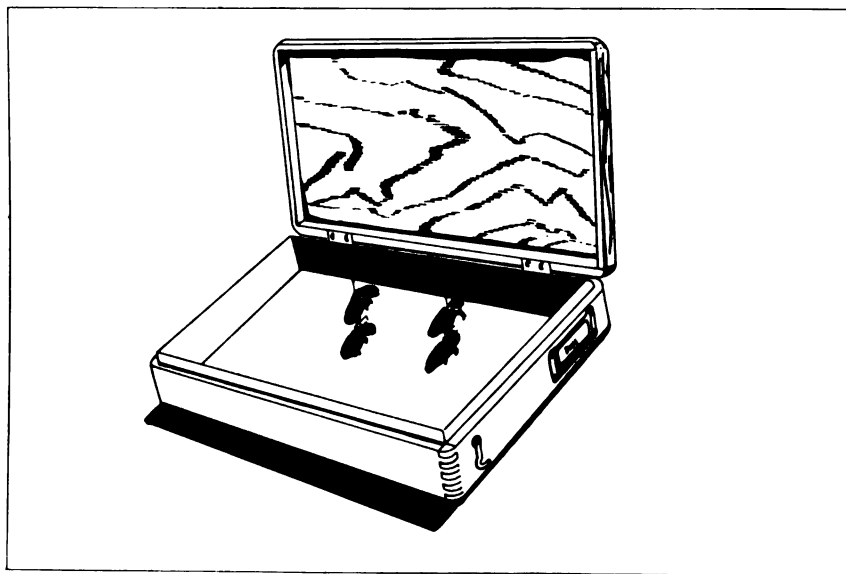
Figure 202.
Schmitt box for pinning specimens.

MOSQUITOES

Adult mosquitoes are usually collected at catching stations, in bait or light traps, or from various daytime resting places. A chloroform tube is commonly used in their capture. Such a tube can be easily prepared by placing a half-inch of cut rubber bands or other rubber scraps in the bottom of a large shell vial or test tube, saturating the rubber with chloroform, covering with a plug of crumpled paper or cotton, and topping with a circle of stiff paper. Various types of suction apparatus are used for taking specimens alive or in large numbers (Fig. 203). The insects are prevented from entering the mouth by a screen mounted over the end·of the sucking tube inside the container.

"Minuten nadeln" pins may be used to mount freshly killed adults as shown in Fig. 204A. The adult mosquitoes may also be glued to paper points, using Duco household cement, orange shellac, or the newer adhesives. Dried specimens should be relaxed before being mounted, care being taken not to rub the specimens or break off the more fragile body parts.
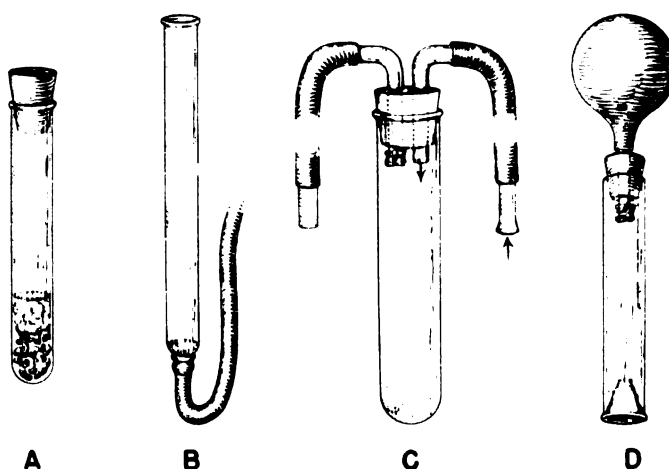
Figure 203.

Aids in collecting adult mosquitoes. A. Chloroform tube.
B, C, D. Types of suction collecting tubes or aspirators.
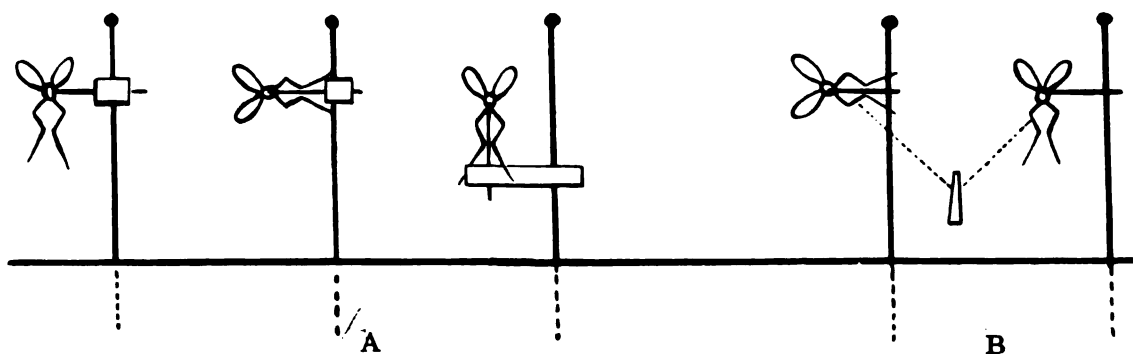
Figure 204.
Adult mosquito specimens mounted for study

286

Unmounted adults can be placed between layers of glazed cotton, cellucotton, or cleansing tissue in pill boxes or salve tins of appropriate size. Plain cotton is objectionable because the specimens become entangled with the fibers and breakage results when they are removed for mounting. The cellucotton expands and contracts, depending upon the humidity; therefore, in humid areas in the tropics, care should be taken to cut the sections of this material large enough to fit snugly even when shrunken from drying. If naphthalene or paradichlorobenzine is added to prevent the development of mold or the attack of insect pests, it should be used sparingly in fine crystals in the bottom of the pill box and should not be allowed to come in contact with the specimens.

A study of male terminalia is sometimes necessary for specific identification. The terminalia must be cleared and mounted on slides for microscopic examination.

Methods of preparation are described in the "Mosquito Atlas," by Ross and Roberts (1943) as follows:

1. Carefully clip off the tip of the abdomen with a pair of fine scissors. Allow the tip to drop from the specimen into a small dish of 70 to 95 per cent alcohol (to moisten).

2. Transfer with a pipet or bent needle to a dish of 10 to 20 per cent KOH for 5 to 20 minutes; longer if it is to be stained.

3. Transfer to a slide in the tip of a pipet. Remove the excess KOH by blotting from the edge of the drop.

4. Add a small drop of glacial acetic acid to neutralize the KOH and partly dehydrate it. Blot off the excess.

5. Add small drops of chloral-gum media. Orient the specimen. Place small bits of glass or paper around the specimen to prevent crushing by the cover slip. Drop the cover slip in place.

If it is desired to use balsam or clarite mounting media, the specimens should be cleared by adding a drop of clove oil or xylol between steps 4 and 5 and the clarite or balsam substituted for chloral-gum in step 5.

In the genus Anopheles the proctiger so obscures the details of the phallosome and claspettes that it is usually desirable to dissect off these latter elements together with the basistyles from the proctiger and ninth segment. This should be done under a dissecting microscope with fine needles just before adding the mounting medium.

Additional methods are described in "A Technique for Staining, Dissecting, and Mounting the Male Terminalia of Mosquitoes," by Komp (1942), Public Health Reports, volume 57, number 36, pages 1327 to 1333.

Fertile anopheline eggs can often be obtained by confining females in a small cage over a dish of water or in a small vial with a few cubic centimeters of water in the bottom. The eggs can be easily recovered by filtering, and the sheets of moist filter paper with the eggs can be packed between layers of damp cotton in a container sealed with paraffin. Eggs packed in this way will remain viable for several days and can be transported to a central laboratory for rearing. A sample batch of eggs on a narrow strip of moist filter paper can be preserved in formaldehyde fumes in a tube tightly corked and sealed with paraffin. A cotton plug saturated with 10 per cent formalin should be placed in the bottom and another dry plug about 1 cm. above it so that the eggs are not directly moistened with formalin. The novocain tube illustrated below is very satisfactory for this method of egg preservation.

Mosquito larvae are usually found floating at the surface of the water where they can be collected by skimming the water with a cup or dipper. The larvae can be removed with a wide-mouthed dropper or spoon and returned to the laboratory for rearing, identification, or perservation. They can be reared on scrapings of dog biscuit, yeast, or crushed toast crumbs; care should be taken to change the water frequently. For quick identification, the examination of a freshly killed larva in a drop of water on a slide is often sufficient. Details are much more readily seen when the specimen is cleared and permanently mounted on a slide. For careful study, all mosquito larvae should be prepared in this way.

Before mounting or preserving mosquito larvae in alcohol, the specimens should be killed in a manner to avoid shrinkage and distortion. Single larval specimens in a drop of water can be killed by holding the slide over a desk lamp for a short time. Larger numbers can be killed by dipping them in hot (not boiling) water for 15 to 20 seconds. For storing, specimens should be run through 50 per cent, then 70 per cent alcohol, and placed in vials with cotton plugs to prevent movement and breakage. Very convenient containers can be made from empty novocain tubes discarded by dental units (Fig. 205).

Figure 205.
Novocain tube for storing mosquito larvae and pupae in alcohol

A number of different media and technics may be used for mounting mosquito larvae and other small arthropods on slides for microscopic study. Following are some of these various materials and technics with their advantages and disadvantages:

Chloral-gum media: The use of Berlesē's formula, or one of its several modifications, is advantageous since no dehydration of the specimen in alcohol is necessary. This reduces handling of larvae to a minimum and lessens the likelihood of mechanical injury. Some difficulty, however, has been experienced with the permanence of these

mounts. Specimens can be killed and mounted directly from water. Mosquito larvae can be killed on a slide as described, excess water drained away with filter paper, gauze, or paper toweling, and one or two drops of the medium placed on the specimen. Small fragments of cover slip or narrow strips of paper, previously saturated in the medium, can be placed on either side of the specimen to prevent crushing by the cover slip. The last few segments of culicine larvae should be pinched off with a needle to allow the breathing tube to appear in full lateral view. The slide should be kept in a horizontal position for several weeks until the medium hardens. The edges of the cover slip should then be ringed with some sealing agent, such as clarite, isobutyl methacrylate, cellulose cement, black asphaltum sealing material, or Duco household cement.

Gater's modification of the chloral-gum formula is commonly used. It may be prepared as follows:

Gum arabic (gum acacia) .... 8 gm.
Distilled water .... 10 ml.
Chlorol hydrate .... 75 gm.
Glycerin .... 5 ml.
Glacial acetic acid .... 3 ml.

The gum arabic is dissolved in water, the action hastened by keeping the water warm, and the other ingredients are added in the order given. The solution can then be strained through several thicknesses of clean muslin, if necessary. Other modifications have been recommended, but the above formula seems the simplest to prepare and its ingredients are available in most laboratories.

Polyvinyl alcohol-phenol-lactic acid medium: Another rapid method for mounting mosquito larvae and other small arthropods without clearing and dehydration in alcohols is through the use of a medium prepared as follows:

Polyvinyl alcohol stock solution .... 56 per cent
Phenol .... 22 per cent
Lactic acid .... 22 per cent

The stock solution is prepared by dissolving the powdered alcohol (duPont – Grade RH-349A) in water until the solution becomes as viscous as thick molasses. This stock solution becomes clear on standing, or clearing can be hastened by heating over a water bath. Specimens can be mounted in this medium as described for chloral-gum and the cover slips ringed in the same way for more permanent slides.

Canada balsam, clarite, and isobutyl methacrylate: For mounting specimens in media which have xylol as a solvent, it is necessary first to dehydrate in 50, 70 and 95 per cent alcohol. The specimens should then be cleared in clove oil, carbolxylol (three parts xylol and one part melted phenol crystals), or absolute alcohol followed

by xylol. The specimens should remain in the various changes at least 15 to 20 minutes. After clearing, they may be mounted in balsam, clarite, or isobutyl methacrylate. With balsam and clarite, hardening of the media may take several days. Isobutyl methacrylate, on the other hand, dries very quickly and slides can be used in a few hours; ringing or sealing is unnecessary. All slides should be fully labeled with locality, date, and collector.

OTHER NEMATOCEROUS DIPTERA

Specimens of the smaller DIPTERA of medical importance - HELEIDAE, PSYCHODIDAE, and SIMULIDAE - are best preserved in 70 per cent alcohol in the field. Phlebotomus adults can later be mounted on slides for careful study; but if Culicoides are mounted in this way, it is often difficult to make out the characteristic color markings on the wings. Simulium adults can also be preserved in alcohol and later dried for mounting. In all three of these groups, specimens may also be preserved dry, as described for mosquito adults, and later mounted in various ways for more detailed study.

MITES

Specimens may be preserved in alcohol and subsequently mounted on slides. For temporary mounts, they may be pipetted onto a glass slide and covered with a drop of 50 per cent alcohol and gently heated over an alcohol lamp. This results in perfect clearing and extension of the specimen so that the finest details of both dorsal and ventral surfaces can be seen.

For permanent mounts, specimens are transferred to a drop of the chloral-medium, covered, heated very gently until bubbling begins, and put aside to set. Specimens can be mounted directly from life, but alcohol specimens must first be washed in distilled water or lactic acid to remove the alcohol. The chloral-gum medium has the advantage of speed in clearing and mounting; specimens may be soaked off in water and remounted at any time.

The following modification of the usual chloral-gum formula has been recommended for mites:

Water .... 35 ml.
Chloral hydrate .... 30 gm.
Gum arabic .... 20 gm.
Glycerin .... 12 ml.
Glucose syrup .... 3 ml.

TICKS

These arachnids can be picked from their host animals or they can be collected by "flagging" -- drawing a rough flannel cloth over the grass and shrubbery in an

infested area -- and then collecting any ticks that become attached to the "flag." They may be preserved in 70 per cent alcohol or cleared and mounted on slides. If slides are to be made, the ticks can be fixed in an extended position by pressing them gently between two glass slides while they are killed by being dipped in hot water. They can be kept in 70 per cent alcohol, cleared in KOH, dehydrated in alcohols, and mounted in balsam, clarite, or isobutyl methacrylate, as described for fleas.

FLEAS

These insects may best be collected from small animals by etherizing the host in a bell jar or other large container and picking up the stupefied fleas that attempt to escape. If the host is killed, it should be dropped immediately into a tight cloth bag to prevent the escape of the fleas that desert the animal as soon as it begins to cool. Dogs or cats may be dusted with ground pyrethrum or derris root, and the fleas picked up from papers spread on the floor under the animal. Specimens may be preserved in 70 per cent alcohol or mounted on slides for specific identification by following the procedure outlined below:

1. Drop living fleas or preserved specimens into 10 per cent KOH and allow to remain a day or two until cleared sufficiently.

2. Transfer to water in a watch glass containing a few drops of HCl; allow to remain one-half hour.

3. Dehydrate by running through 50 per cent alcohol and 95 per cent alcohol for one-half hour each.

4. Clear in beechwood creosote for 1 hour or run through several changes of absolute alcohol and clear in clove oil or xylol.

5. Mount on slides in balsam, isobutyl methacrylate, or clarite.

6. Label fully, including host animal, locality, date, and collector's name.

MISCELLANEOUS ARTHROPODS

Spiders, scorpions, centipedes, millipedes, lice, bedbugs, maggots and other larvae, nymphs and other soft-bodied insects may be preserved in vials of 70 per cent alcohol, the corks paraffined to prevent loss through evaporation. If a small amount of glycerin is added to each vial, the specimens will not become dry and shrunken should the alcohol be accidentally lost. If the vials are kept upright, the corks will remain dry and stay in good condition much longer than otherwise. The larger, hard-bodied adult insects may be pinned and labeled carefully and stored in Schmidt boxes or cigar boxes. Care should be taken to keep specimens dry and to prevent mold and damage by insect pests. The addition of a small amount of naphthalene flakes or para-dichlorobenzene to storage boxes will prevent such damage.

B. DISSECTION OF MOSQUITOES FOR MALARIA PARASITES

MATERIALS AND APPARATUS

1. Glass slides
2. Small cover slips
3. Curved forceps
4. Needles, points flattened and sharpened, mounted in suitable holders
5. Safety razor blade
6. Small triangles of filter paper
7. Physiological saline
8. Physiological saline deeply tinted with methylene blue
9. Pipets or droppers

PROCEDURES

In selecting mosquitoes for dissection, avoid using those containing recently ingested blood or those in which the abdomen is distended by the fully developed ovaries. Recently engorged mosquitoes will show a dark, swollen area in the ventral abdominal region. These may be kept in tubes with moist cotton plugs or in humid cages for 48 hours to allow digestion of the blood meal. If it is necessary to examine a recently engorged mosquito, carefully prick the abdomen and squeeze out the blood.

1. Kill the mosquitoes with chloroform, only one or two at a time.
2. Identify and record the species.
3. Remove the legs and wings with needles.
4. Place the insect on a slide and sever the abdomen with a clean cut of the razor blade.
5. Transfer the head and thorax to a drop of tinted saline on another slide.

Malpighian tubules

Nick integument with needle

Stomach

Salivary glands
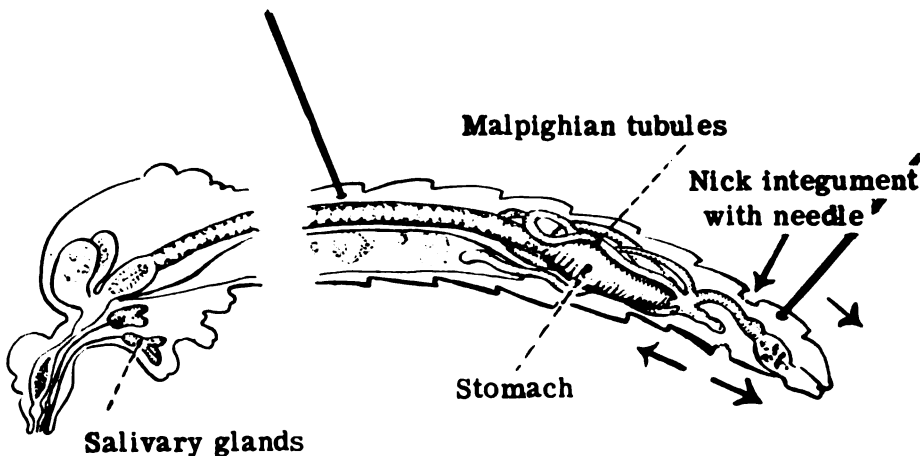
Figure 206.
Dissection for malaria parasites

292

DISSECTION OF STOMACH

1. Place the abdomen on a black background, illuminate with a strong direct light.

2. Immerse in a large drop of physiological saline.

3. With the needles, nick the integument on both sides just in front of the terminal segments, as shown in Fig. 206.

4. Place the point of one needle on the terminal segments, the other on the integument at the anterior end; by gentle traction draw out the stomach with the attached Malpighian tubules and ovaries.

5. Remove most of the saline with a triangle of filter paper.

6. Cut off the Malpighian tubules close to their attachments and the gut posterior to the stomach. Sweep away with the ovaries, eggs, and other debris.

7. Add fresh saline and gently lower a cover slip onto the stomach.

8. Withdraw sufficient saline so that the stomach flattens out, and examine under the low and high power of a compound microscope.

9. The stomach can be rolled over by adding saline and gently moving the cover slip.

10. Watch for oocysts on the outside wall, examining for protrusions which may appear as follows (Fig. 207 A.).

   a. Young oocysts - clear, round, or oval bodies, more refractile than stomach cells, containing minute pigmented granules, measuring 6 to 12 microns in diameter.

   b. Older oocysts - denser than the stomach, with clumps of pigment.

   c. Mature oocysts - measure 30 to 80 microns in diameter, appear finely striated, and contain enormous numbers of refractile, spindle-shaped sporozoites that are 12 to 14 microns in length.

A positive diagnosis should not be made unless pigment granules are visible within the object, since small protrusions of the stomach membrane or fat cells may simulate immature oocysts. It must also be remembered that it is impossible to distinguish between bird and human malaria in the mosquito.

DISSECTION OF SALIVARY GLANDS

1. Place the head and thorax in the blue-tinted saline against a white background, with the head toward the right.

2. Hold the thorax with the left needle, drawing the head down and forward with the right.

3. Usually the salivary glands will come out in a tag of tissue attached to the head. They may be recognized by their trilobed form, shining appearance, and deep blue tint (Fig. 207B). If they do not come out, they may be recovered by tearing apart the tissues near the neck attachment.

4. Isolate the salivary glands, remove the debris, and add plain saline and a cover slip.

5. Remove any excess saline and rupture the salivary glands by pressing the cover slip lightly with a needle.

6. Examine for sporozoites (Fig. 207C.) under high power (500 diameters). Sporozoites are slender, refractile, spindle-shaped bodies, which sometimes move with a slow end-to-end motion. The final test is to remove the cover slip, allow the saline to dry, and stain with Giemsa or Wright's stain. Under the oil immersion lens, the sporozoites should appear as slender blue-stained spindles with a central red chromatin dot.
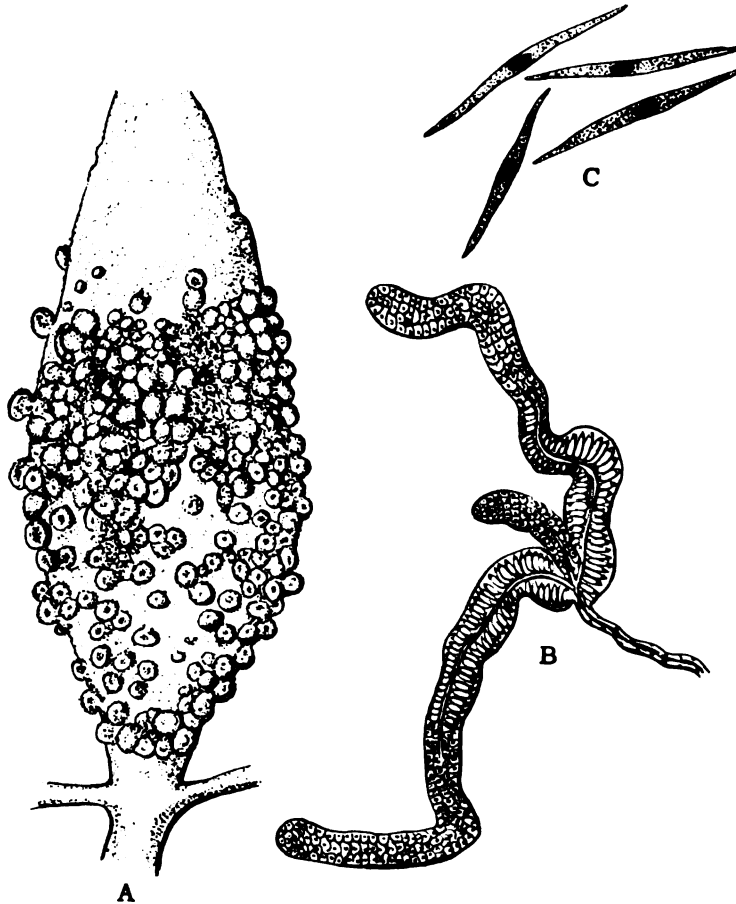
Figure 207.
A. Stomach with a heavy oocyst infection
B. Salivary gland. C. Sporozoites

294

C. DISSECTION OF MOSQUITOES FOR FILARIAL PARASITES

In areas where filariasis is endemic it is sometimes desirable to dissect mosquitoes to determine the number infected.

PROCEDURE

1. Kill the female mosquitoes, a few at a time, with chloroform, carbon tetrachloride, or tobacco smoke and identify the species. Do not dissect recently engorged mosquitoes. Remove legs and wings, dip quickly into 35 to 50 per cent alcohol, and place at the edge of a drop of physiologic saline.

2. Sever the head and place in a separate drop of saline. Carefully dissect the thorax, teasing all tissues apart, add the cover glass, and examine for developing parasites.

3. Carefully dissect the proboscis and head for the presence of infective larvae which are usually 1 mm. or more in length.

D. DETERMINATION OF CHLORIDES IN BRACKISH WATER

The brackish condition of habitat water is of primary concern in any mosquito control or survey operation. Certain species thrive in the presence of high salinity while others cannot tolerate even small amounts. Presented in the following section are methods of determining the chloride content and the total salts.

REPLACEMENT METHOD

Equipment: Buret
     Buret stand
     Evaporating dish – 6 inches
     Brown bottle for silver nitrate
     Dropping bottle
     Graduated pipets

Reagents: Standardized silver nitrate solution made by dissolving 4.791 gm. of pure recrystallized silver nitrate in distilled water to make 1 liter.
     Saturated solution of potassium chromate
     Calcium carbonate

Method: Transfer 1 to 10 ml. (depending on the amount of chloride expected) of the sample to the evaporating dish; add 100 ml. of distilled water, 1 ml. of the chromate indicator, and a small pinch of calcium carbonate (to counteract any possible acidity of the sample); add the standard silver nitrate solution from the buret to the stirred sample until the color changes from light yellow to pink; run a blank determination on the reagents -- that is, go through the regular procedure using no sample -- to determine how much silver solution is required to produce the color change which the operator recognizes as the end point; subtract this blank from all titrations and make the following calculations:

Parts chloride per 1,000,000 parts of sample =

$$\frac{\text{corrected titration in milliliters x 1,000}}{\text{milliliters of sample taken}}$$

Discussion: The brackish condition of water is due to the presence of salts (as chlorides, bromides, sulfates). In pools where mosquitoes are breeding, the salts responsible for the brackish condition may be dissolved from the ground around the pool by leaching or may be derived from ocean water or both. In practically all brackish water situations, the halide salts (chlorides, bromides, and iodides) are present in large quantities, while the nonhalide salts (sulfates and carbonates) are present in very small quantities. The determination of the halide content (which is expressed as chlorides) of a pool gives a comparative, but not absolute, indication of the brackishness of the water.

If the chloride content in a sample of ocean water is known, it is possible to apply an empirical formula and determine the total salts present. This is due to the fact that although the total salt content of ocean water varies in different parts of the world -- higher in equatorial regions, lower in polar regions and on the continental shelves -- the relative quantities of the component salts remain the same. The total salinity of a sample of sea water or of brackish water can be determined by the following formula:

$$\text{Salinity} = 0.030 \; \div \; 1.8050 \; x \; \text{chlorides in ppm.}$$

There are only a few instances where water in a pool containing mosquito larvae would have salts in the same proportion as found in sea water. It is desirable, therefore, to express the brackish condition of water in terms of the halides (expressed as chlorides) present.

SPECIFIC GRAVITY METHOD

Specific gravity is defined as the ratio of the weight of any volume of a substance to the weight of an equal volume of some other substance taken as a standard, the measurements being made at the same temperature. Pure water at 4° C. is taken as

the standard and is assumed to have a specific gravity of 1 when dealing with solids or liquids. In brackish water pools, the dissolved salts increase the weight of the water and therefore the specific gravity. It is possible then, by determining the specific gravity of a sample of water from the pool, to obtain a rough idea of the salt content. Naturally, there are severe limitations to this method, since any substance dissolved in the sample, whether chlorides or not, will affect the specific gravity.

The instrument used to measure specific gravity is known as a hydrometer. A crude hydrometer may be made by weighting one end of a stick treated to make it impervious to water. This stick will float upright at a level that is dependent upon the specific gravity of the solution in which it is placed. The stick may be calibrated by placing it in distilled water and marking it at exactly the water surface. Whenever the stick floats at this level subsequently, it will indicate that the medium in which it floats has a specific gravity of 1. By placing the stick in other solutions of known specific gravities, other indicator marks may be added at the appropriate places. The type of hydrometer that is most useful in this work is the one used in clinical laboratories, known as a urinometer. This is calibrated so that it is possible to read specific gravities to the third decimal place (thousandths). A urinometer and a small graduate may be carried in the field kit, and specific gravities taken and recorded on the spot. Special care should be taken to see that the urinometer is carefully calibrated in distilled water before use, and any necessary correction factor noted.

If the sample tested is from a pool formed from ocean water, it is possible to estimate the chloride content by use of table III and the total salt content by the further use of the formula:

$$\text{Salinity} = 0.030 + 1.8050 \times \text{chlorides in ppm.}$$

It must be borne in mind that this conversion is valid only in coastal areas where the salts present have their origin from ocean water. It is absolutely useless in such situations as land-locked bodies of brackish water where the component salts are in different proportions than in ocean water. Since various writers may express salinities of brackish water habitats differently -- chlorides in parts per million, total salts in parts per million, per cent sodium chloride, grams of sodium chloride per liter, and as percentages of sea water -- additional tables are presented to enable the investigator to reduce these readings to a common standard for work in mosquito biology.

Table I*

Per cent Sea Water	Chloride in ppm.
100	20,000
95	19,000
90	18,000
85	17,000
80	16,000
75	15,000
70	14,000
65	13,000
60	12,000
55	11,000
50	10,000
45	9,000
40	8,000
35	7,000
30	6,000
25	5,000
20	4,000
15	3,000
10	2,000
5	1,000
0	0

Table II**

Specific Gravity	Per cent NaCl
1.00172	.220
1.00227	.292
1.00310	.400
1.00393	.508
1.00476	.617
1.00531	.689
1.00614	.797
1.00696	.906
1.00751	.978
1.00834	1.086
1.00916	1.194
1.00999	1.303
1.01081	1.411
1.01136	1.483
1.01219	1.591
1.01301	1.700
1.01383	1.808
1.01466	1.916
1.01521	1.989
1.01603	2.097
1.01685	2.205
1.01740	2.277
1.01823	2.386
1.01905	2.494
1.11988	2.602
1.02070	2.711
1.02025	2.783
1.02208	2,891
1.02291	2.999
1.02373	3.108
1.02456	3.216
1.02511	3.288
1.02594	3.396
1.02677	3.505
1.02760	3.613
1.02815	3.685
1.02899	3.794
1.02982	3.902
1.03065	4.010
1.03149	4.118

Table III

Specific Gravity	Chloride in ppm.
1.001	741
1.002	1,483
1.003	2,224
1.004	2,965
1.005	3,706
1.006	4,447
1.007	5,188
1.008	5,929
1.009	6,670
1.010	7,411
1.011	8,152
1.012	8,893
1.013	9,634
1.014	10,375
1.015	11,116
1.016	11,858
1.017	12,598
1.018	13,339
1.019	14,080
1.020	14,821
1.021	15,562
1.022	16,303
1.023	17,044
1.024	17,785
1.025	18,526
1.026	19,267
1.027	20,000

Total salinity $= 0.030 + 1.8050 \times$ chlorides in ppm.

(Knudson's Formula)

* This table applies where sea water tests 20,000 ppm. of chlorides.

** From Roth and Scheel "Physikalischchemische Tabellen" -- specific gravities of various concentrations of salt in sea water (at water and air temperature of 17.5°C)

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SECTION V.

SUMMARIES, KEYS AND DEPARTMENTAL RESPONSIBILITY

FOR VECTOR CONTROL

SUMMARY OF THE MORE IMPORTANT ARTHROPOD
VECTORS OF HUMAN DISEASE

VECTOR	DISEASE	SPECIFIC AGENT
Class DIPLOPODA		
Millipedes	Hymenolepiasis	Hymenolepis diminuta
Class CRUSTACEA		
Copepoda (water fleas)	Diphyllobothriasis	Diphyllobothrium latum
	Dracontiasis	Dracunculus medinensis
	Gnathostomiasis	Gnathostoma spinigerum
	Sparganosis	Diphyllobothrium spp.
Decapoda (crayfish, crabs, etc.)	Paragonimiasis	Paragonimus westermani
Class ARACHNIDA	Bertelliasis	Bertiella studeri
Mites	Rickettsialpox	Rickettsia akari
	Tsutsugamushi	Rickettsia tsutsugamushi
Ticks	Boutonneuse fever	Rickettsia conori
	Bullis fever	Rickettsia sp.
	Colorado tick fever	Filtrable virus
	Encephalitis, Russian spring, summer	Erro sylvestris virus
	Louping ill	Virus sp.
	Maculatum disease	Rickettsia sp.
	Plague	Pasteurella pestis
	Q Fever	Coxiella burneti
	Relapsing fever (endemic)	Borrelia duttoni
	Spotted fever	Rickettsia rickettsia
	Tularemia	Pasteurella tularensis
Class INSECTA		
Black flies	Onchocerciasis	Onchocerca volvulus
	Tularemia	Pasteurella tularensis
Cockroaches	Amebiasis	Endamoeba histolytica
	Balantidiasis	Balantidium coli
	Cholera	Vibrio comma (cholera)
	Dysentery, bacillary	Shigella spp.
	Food poisoning	Staphylococcus sp.
		Salmonella sp.
		Streptococcus sp.

VECTOR	DISEASE	SPECIFIC AGENT
Cockroaches (cont.)	Giardiasis	Giardia lamblia
	Gongylonemiasis	Gongylonema pulchrum
	Hymenolepiasis	Hymenolepis diminuta
	Poliomyelitis	Virus types 1, 2, 3
	Paratyphoid fever	Salmonella spp.
	Typhoid fever	Salmonella typhosa
Cone-nose bugs	Trypanosomiasis (Chagas')	Trypanosoma cruzi
Deer flies	Loaiasis	Loa loa
	Tularemia	Pasteurella tularensis
Eye Gnats	Conjunctivitis	Bacteria spp.
	Tropical ulcer	Mixed bacteria & spirochete flora
	Trachoma	Virus
	Yaws	Treponema pertenue
Fleas	Dipylidiasis	Dipylidium caninum
	Hymenolepiasis	Hymenolepis diminuta
	Plague	Pasteurella pestis
	Typhus fever (endemic)	Rickettsia typhi
House fly and other filth flies	Amebiasis	Endamoeba histolytica
	Bacillary Dysentery	Shigella spp.
	Balantidiasis	Balantidium coli
	Cholera	Vibrio comma (cholera)
	Cysticercosis	Taenia solium
	Food poisoning	Staphlococcus sp.
		Salmonella sp.
		Streptococcus sp.
	Giardiasis	Giardia lamblia
	Paratyphoid fever	Salmonella sp.
	Poliomyelitis	Virus types 1, 2, 3.
	Trachoma	Virus
	Trichuriasis	Trichuris trichiura
	Tropical ulcer	Mixed bacteria & sprochete flora
	Typhoid fever	Salmonella typhi
	Yaws	Treponema pertenue

VECTOR	DISEASE	SPECIFIC AGENT
Lice	Relapsing fever (epidemic)	Borrelia recurrentis
	Trench fever	Rickettsia quintana
	Typhus fever (epidemic)	Rickettsia prowazeki
Mosquitoes	Dengue	Charon sp. virus
	Encephalitis	
	California	
	Equine, Eastern	
	Venezuelan	
	Western	Virus
	Japanese B	
	Russian, spring-summer	
	West Nile	
	Filariasis, Bancroft's	Wuchereria bancrofti
	" Malayan	W. malayi
	Malaria	Plasmodium spp.
	Myiasis	Dermatobia hominis
	Rift Valley fever	virus
	Tularemia	Pasteurella tularense
	Yellow fever	Charon evagatus
Moths & beetles	Hymenolepiasis	Hymenolepis diminuta
Biting gnats	Acanthocheilonemiasis	Acanthocheilonema perstans
	Mansonelliasis	Mansonella ozzardi
	Microfilaria streptocerca	Acanthocheilonema strepto-cerca
Sand flies	Bartonellosis	Bartonella bacilliformis
	Espundia	Leishmania brasiliensis
	Kala-azar	L. donovani
	Oriental sore	L. tropica
	Sandfly fever	Pappataci virus
Tsetse flies	Trypanosomiasis	Trypanosoma gambiense
		T. rhodesiense

302

SUMMARY OF THE MORE IMPORTANT HUMAN DISEASES
TRANSMITTED BY ARTHROPODS

DISEASES AND IMPORTANT VECTORS	KNOWN REGION OF TRANSMISSION
BACTERIA	
CHOLERA	
Transmitted in part by:	
Musca spp.	
Other filth flies	Cosmopolitan
Blattidae	Cosmopolitan
CONJUNCTIVITIS	
Transmitted in part by:	
Hemophilus spp.	United States
Hippelates collusor	California
H. flavipes	Florida, Texas, Georgia, Alabama
H. pallipes	West Indies
Siphunculina funicola	India
Musca domestica complex	Egypt, India, Indonesia
Musca sorbens	Egypt, India
Oscinis pallipes	Egypt
DYSENTERY	
Transmitted in part by:	
Musca spp.	
Other filth flies	Cosmopolitan
Blattidae	Cosmopolitan
PLAGUE (Black death)	
Transmitted by fleas:	
Citellophilus tesquorum	Mongolia
Chiastopsyllus rossi	South Africa
Diamanus montanus	California and Oregon
Dinopsyllus lypusus	South Africa
Hoplopsyllus anomalus	California and Oregon
Nosopsyllus fasciatus	Temperate zone
Oropsylla silantiewi	Mongolia
Pulex irritans	Cosmopolitan
Rhopalopsyllus cavicola	Argentina and Ecuador
Synosternus pallidus	West Africa
Xenopsylla astia	India, Ceylon, Burma, Mesopotamia, Mombasa
X. brasiliensis	Belgian Congo, Kenya, Uganda, Bechuanaland
X. cheopis	Cosmopolitan
X. eridos	South Africa
X. nubicus	Tropical East and West Africa

303

DISEASES AND IMPORTANT VECTORS	KNOWN REGION OF TRANSMISSION
TULAREMIA (Deer fly fever, rabbit fever)	
Transmitted by deer flies, ticks and mosquitoes	
Amblyomma americanum	United States
Dermacentor andersoni	United States
D. variabilis	United States
D. silvarum	U.S.S.R.
Aedes cinereus	Sweden
Culex apicalis	U.S.S.R.
Chrysops discalis	Western U.S.A.
TYPHOID AND PARATYPHOID FEVER	
Transmitted in part by:	
Musca spp.	
Other filth flies	Cosmopolitan
Blattidae	Cosmopolitan
HELMINTHS	
CESTODES	
BERTIELLIASIS	
Caused by ingesting infected mites	
Orbatid mites	Africa, Asia, Mauritius, West Indies
CYSTICERCOSIS (Bladder worm)	
Transmitted in part by non-biting flies	
Musca domestica	
Other filth flies	Cosmopolitan
DIPHYLLOBOTHRIASIS (Fish tapeworm)	
Caused by ingesting fish which have eaten infected copepods	
Cyclops spp.	Europe and North America, Japan
Diaptomus spp.	and scattered areas of Africa
DIPYLIDIASIS (Dog tapeworm)	
Caused by ingesting infected fleas or biting lice	
Ctenocephalides canis	
C. felis	Cosmopolitan
Pulex irritans	
Trichodectes canis	

304

DISEASES AND IMPORTANT VECTORS	KNOWN REGION OF TRANSMISSION
HYMENOLEPIASIS DIMINUTA (Rat tapeworm disease)	
Caused by the ingestion of infected arthropods	
Coleoptera	
Dermaptera	
Diplopoda	
Lepidoptera	India, U.S.S.R., Japan, Italy, United States
Orthoptera	
Siphonaptera	
HYMENOLEPIASIS NANA (Dwarf tapeworm)	
Caused by ingestion of infected beetles and fleas	
Coleoptera	Cosmopolitan
Siphonaptera	
SPARGANOSIS (Sparganum infection)	
Caused by ingestion of infected copods	
Cyclops spp.	Japan, China, Korea, Formosa, Indochina, Africa, Australia, Java & Sumatra, Holland, British Guiana, parts of United States
NEMATODES	
Intestine inhabiting	
TRICHURIASIS (Whip worm)	
Transmitted in part by:	
Musca spp.	
Other filth flies	
Mechanical transmission of a number of other nematode species	Cosmopolitan
Tissue inhabiting	
ACANTHOCHEILONEMIASIS	
Transmitted by biting gnats	Rain forests West and Central Africa,
Culicoides austeni	Tropical South America and New Guinea,
C. grahami	and coastally in Trinidad and Panama
BANCROFT'S FILARIASIS	
Culex quinquefasciatus	Cosmopolitan
C. pipiens	Central China, Japan and Egypt
Aedes aegypti	West Africa, Belgian Congo, New South Wales, Surinam, St. Croix, West Indies
Anopheles albimanus	Caribbean area
Anopheles darlingi	Brazil

305

DISEASES AND IMPORTANT VECTORS	KNOWN REGION OF TRANSMISSION
<u>NEMATODES</u> (cont.)	
<u>BANCROFT'S FILARIASIS</u> (cont.)	
<u>A</u>. <u>gambiae</u>	West Africa, Belgian Congo, Zanzibar
<u>A</u>. <u>punctulatus</u> (3 var.)	New Guinea, various South Pacific Islands,
<u>A</u>. <u>stephensi</u>	India
<u>Aedes</u> <u>polynesiensis</u>	Numerous Polynesien Islands
Other species totaling	
nearly 60 in all	
DRACONTIASIS (Guinea worm)	
<u>Cyclops</u> spp.	Africa, India, U.S.S.R., Middle East.
GNATHOSTOMIASIS	Thailand, Malay States, China, Japan, India,
<u>Cyclops</u> sp.	Java, Palestine, Indochina, Philippines,
GONGYLONEMIASIS	Italy, Bulgaria, United States, U.S.S.R.
Blattidae	Ceylon, China
LOAIASIS (Eye worm)	
Transmitted by deer flies	
<u>Chrysops</u> <u>dimidiata</u>	Tropical Africa, Congo River Basin especially
<u>C</u>. <u>distinctpennis</u>	
<u>C</u>. <u>silacea</u>	
MALAYAN FILARIASIS	
Transmitted by mosquitoes	
<u>Anopheles</u> <u>barbirostris</u>	Indonesia, Malaya and China
<u>A</u>. <u>hyrcanus</u> complex	Indonesia, Malaya and China
<u>A</u>. <u>umbrosus</u>	Malaya
<u>Mansonia</u> <u>annulata</u>	Indonesia, Malaya, and Philippines
<u>Mansonia</u> <u>annulifera</u>	Indonesia, Malaya, India, and Ceylon
<u>M</u>. <u>indiana</u>	Malaya
<u>M</u>. <u>longipalpis</u>	Malaya
<u>M</u>. <u>uniformis</u>	Malaya
MANSONELLIASIS (Ozzard's	
filariasis)	
Transmitted by biting gnats	
<u>Culicoides</u> <u>furens</u>	West Indies, Central and South America
ONCHOCERCIASIS (Blinding fil-	
ariasis)	
Transmitted by black flies	
<u>Simulium</u> <u>callidum</u>	Guatemala, Southern Mexico
<u>S</u>. <u>metallicum</u>	Guatemala, Southern Mexico
<u>S</u>. <u>ochraceum</u>	Guatemala, Southern Mexico
<u>S</u>. <u>damnosum</u>	Tropical Africa
<u>S</u>. <u>neavei</u>	Tropical Africa

DISEASES AND IMPORTANT VECTORS	KNOWN REGION OF TRANSMISSION
<u>TREMATODES</u>	
PARAGONIMIASIS (Lung fluke)	
Caused by ingesting infected	
crabs and crayfish	
<u>Astacus japonicus</u>	Orient
<u>A. similis</u>	Orient
<u>Eliocheir sinensis</u>	China
<u>Potoman dehaani</u>	Africa, China, South America
<u>P. denticulatus</u>	Orient
<u>Pseudothlphusa iturbei</u>	Venezuela
<u>PROTOZOA</u>	
AMEBIASIS (<u>Endamoeba histolytica</u>)	
BALANTIDIASIS (<u>Balantidium coli</u>)	
GIARDIASIS (<u>Giardia lamblia</u>)	
Transmitted in part by:	
<u>Musca</u> spp.	Cosmopolitan
Other filth flies	Cosmopolitan
Blattidae	Cosmopolitan
LEISHMANIASIS	
ESPUNDIA (muco-cutaneous)	
Transmitted by sand flies	
<u>Phlebotomus</u> spp.	Central and South America
KALA-AZAR (visceral)	
Transmitted by sand flies	
<u>Phlebotomus argentipes</u>	India
<u>P. chinensis</u>	China
<u>P. intermedius</u>	South America
<u>P. longipalpis</u>	Brazil
<u>P. major</u>	Greece
<u>P. perniciosus</u>	Italy, Sicily
<u>P. sergenti mongolensis</u>	China
ORIENTAL SORE (cutaneous)	
Transmitted by sand flies	
<u>Phlebotomus papatasii</u>	India
<u>Phlebotomus</u> spp.	Africa, Asia
MALARIA	
<u>Anopheles</u> spp.	64° North to 32° South in tropical and tem-
(Detailed list under "Control	perate zones except certain Islands.
of Malaria Vectors" in Sec-	
tion II)	

DISEASES AND IMPORTANT VECTORS	KNOWN REGION OF TRANSMISSION

TRYPANOSOMIASIS
  AFRICAN (Sleeping Sickness)
    Transmitted by tsetse flies

Glossina palpalis	Gambian type	Equatorial Africa
G. tachinoids	Gambian type	West Africa
G. morsitans	Rhodesian type	East Africa
G. swynnertoni	Rhodesian type	Tongonyika

  SOUTH AMERICAN (Chagas' Disease)
    Transmitted by assassin bugs

Panstrongylus spp.	Panama, South America
Rhodnius spp.	South America, Mexico
Triatoma spp.	United States, South America, Mexico and Central America

    Other genera and species
RICKETTSIA
  FLEA BORNE
    TYPHUS, ENDEMIC (Murine or
                sporadic typhus)

Ctenocephalides felis	Texas
Nosopsyllus fasciatus	Europe, North America
Xenopsylla cheopis	Cosmopolitan
X. astia	Orient

  LOUSE BORNE
    TRENCH FEVER (Five day fever)

Pediculus humanus	Western Ukraine (sporadic)

    TYPHUS, EPIDEMIC (Jail fever,
        ship fever, louse typhus)

Pediculus humanus	Cosmopolitan

  MITE BORNE
    RICKETTSIALPOX (Kew Gardens
        spotted fever)

Allodermanyssus sanguineus	North Atlantic Seaboard, U.S.A.

    TYPHUS, SCRUB (Japanese river
        fever, Kedani fever, Tsutsu-
        gamushi, pseudotyphus,
        Sumatra fever, New Guinea
        mite typhus, Queensland
        Coastal fever)   Japan, Australasian region, East Indies, Philippines
      Trombicula akamushi
      T. deliensis
      T. fuji

DISEASES AND IMPORTANT VECTORS	KNOWN REGION OF TRANSMISSION
TICK BORNE	
BOUTONNEUSE FEVER (Tick typhus South African tick fever, North Queensland tick typhus, Siberian tick typhus)	
Amblyomma hebraeum	East, Central and South Africa
Haemaphysalis leachi	East, Central and South Africa
Hyalomma rufipes	East, Central and South Africa
Rhipicephalus appendiculatus	East, Central and South Africa
R. evertsi	East, Central and South Africa
R. simus	East, Central and South Africa
R. sanguineus	Mediterranean Basin, the Crimea & India
Ixodes holocyclus	North and South Queensland
Dermacentor nuttali	Russia-Eastern & Central Siberia
D. silvarum	Russia-Eastern & Central Siberia
Haemaphysalis concinna	Russia-Eastern & Central Siberia
BULLIS FEVER (Lone Star fever)	
Amblyomma americanum	Texas
SPOTTED FEVER (Rocky mountain spotted fever, American spotted fever, Tobia fever, Sao Paulo fever, Choix fever, Pinto fever)	
Amblyomma americanum	Oklahoma & Texas
Dermacentor andersoni	Western United States
D. variabilis	Eastern & Southern United States
Amblyomma brasiliensis	Panama, Colombia, Brazil
A. cajennense	Panama, Colombia, Brazil
A. striatum	Panama, Colombia, Brazil
Rhipicephalus sanguineus	Mexico
MACULATUM DISEASE	
Amblyomma maculatum	South Central and Southeastern United States
"Q" FEVER (Nine mile fever, Balkan grippe)	
Seventeen tick species naturally infected, of little or no importance in transmission	Cosmopolitan

DISEASES AND IMPORTANT VECTORS	KNOWN REGION OF TRANSMISSION
VIRUS DISEASES	
COLORADO TICK FEVER	
Dermacentor andersoni	Western United States
DENGUE (Break-bone fever)	
Transmitted by mosquitoes	
Aëdes aegypti	Cosmopolitan in warm climates
A. albopictus & other members	Sino-Japanese area, Philippines,
of the Stegomyia group	Sumatra and Hawaii
Armigeres obturbans	Formosa
RIFT VALLEY FEVER	
Transmitted by mosquitoes	
Eretmapodites spp.	Africa
Aedes tarsalis	Africa
A. de-boeri	Africa
SAND FLY FEVER (Pappataci fever)	
Transmitted by sandflies	
Phlebotomus papatasi	Tropics & Subtropics
Phlebotomus spp.	
TRACHOMA	
Transmitted in part by:	
Musca domestica	Cosmopolitan
Musca domestica vicina	Replaces domestica in Egypt; Middle East
Musca sorbens	Egypt, Middle East
Other Filth Flies	
Eye gnats	
YELLOW FEVER	
Jungle	
Haemagogus spegazzinii	South America
Aedes leucocelaenus	South America
Aedes simpsoni	Africa
A. africanus	Africa
Urban	
Aedes aegypti	Central and South America, Africa

C.N.S.* VIRAL INFECTIONS

CALIFORNIA VIRUS
Transmitted by mosquitoes

Aedes dorsalis	San Joaquin Valley
Culex tarsalis	California

EQUINE, EASTERN
Transmitted by mosquitoes,
mites, and lice

Culiseta melanura	United States (Louisiana)
Mansonia perturbans	United States (Georgia)
Dermanyssus gallinae	United States (Tennessee)
Eomenacanthus stramineus	United States (Tennessee)

EQUINE, WESTERN
Transmitted by mosquitoes,
mites & possibly cone nose bugs

Culex tarsalis	United States (Washington, California, Nebraska)
Culex spp.	
Aedes dorsalis	United States
Culiseta inornata	United States
Anopheles freeborni	United States
Dermanyssus gallinae	United States
D. americanus	United States
Liponyssus bursa	United States
Liponyssus sylviarum	United States
Triatoma sanguisuga	United States

EQUINE, VENEZUELAN
Transmitted by mosquitoes

Aedes taeniorhynchus	South America
Mansonia titillans	Trinidad, B.W.I.
Anopheles neomaculipalpis	South America

JAPANESE B.
Transmitted by mosquitoes

Aedes chemulpoensis	North China
Culex tritaeniorhynchus	U.S.S.R. and much of the Far East
Culex fatigans	U.S.S.R. and much of the Far East
Culex annulirostris	U.S.S.R. and much of the Far East
Culex pipiens, var. pallens	Sino-Japanese areas, Southwest Pacific Islands and the Maritime Provinces of Siberia
Anopheles spp.	U.S.S.R.
Ixodes persulcatus	U.S.S.R.

* Central Nervous System

DISEASES AND IMPORTANT VECTORS	KNOWN REGION OF TRANSMISSION
ILHEUS	
Transmitted by mosquitoes	
Aëdes aegypti	Brazil
A. serratus	Brazil
Psorophora ferox	Brazil
LOUPING ILL.	
Transmitted by ticks	
Ixodes ricinus	England, Scotland, Czechoslovakia
MURRAY VALLEY	
Transmitted by mosquitoes (probably)	
RUSSIAN SPRING-SUMMER	
Transmitted by ticks	
Haemaphysalis concinna	European U.S.S.R., Siberia, Far Eastern Maritime provinces
H. japonica	Eastern Maritime provinces
Dermacentor silvarum	Eastern Maritime provinces
Ixodes persulcatus	U.S.S.R.
SEMLIKI FOREST	
Aëdes abnormalis	Uganda
ST. LOUIS	
Transmitted by mites and mosquitoes	
Dermanyssus gallinae	United States
Culex tarsalis	United States
C. pipiens	United States
Aëdes dorsalis	United States
Culex quinquefasciatus	United States
WEST NILE	
Transmitted by mosquitoes	Tropical Africa
Culex antennatus	Tropical Africa
C. pipens	Tropical Africa
C. univittatus	Tropical Africa
POLIOMYELITIS (Infantile Paralysis)	
Transmitted in part by:	
Musca spp.	Cosmopolitan
Other filth flies	
Blattidae	Cosmopolitan

312

DISEASE AND IMPORTANT VECTORS	KNOWN REGION OF TRANSMISSION
SPIROCHETES	
RELAPSING FEVER	
ENDEMIC (Tick borne)	
Ornithodoros asperus	Asia
O. crossi	Northern India
O. erraticus	Portugal, Spain, Tunisia
O. hermsi	Western United Sates, British Columbia
O. marocanus	Morocco, Spain
O. moubata	Africa
O. parkeri	Western United States
O. rudis	Central & South America, Mexico
O. savignyi	Africa
O. talaje	Central & South America
O. tartakovskyi	U.S.S.R
O. tnolozani	Iran, Iraq, Syria, Israel, Cyprus, USSR
O. turicata	Mexico, Western United States
O. verrucosus	Iran
EPIDEMIC (Louse borne)	
Pediculus humanus	Cosmopolitan
TROPICAL ULCER (Naga sore)	
Musca spp.	Cosmopolitan, tropical areas
Other filth flies	
Sarcophaga spp.	
YAWS	
Transmitted in part by:	
Hippelates flavipes	Caribbean region
Musca domestica complex	Africa & subtropical regions

MISCELLANEOUS INFECTIONS AND INFESTATIONS CAUSED BY ARTHROPODS

DISEASES AND IMPORTANT ARTHROPODS	KNOWN REGION OF TRANSMISSION
ARACHNIDISM	
NECROTIC (Mancha gangrenusa or gangrenous spot)	
Loxasceles laëta	Chile, Uruguay
SYSTEMIC	
Atrax formidabilis	Australia
A. robustus	Australia
Ctenus and Lycosa spp.	Brazil
Latrodectus concinnus	South Africa
L. erebus	Egypt, Spain, South U.S.S.R.
L. foliatus	South America
L. geometricus	West Indies, Panama, Brazil, Luzon, California, Cuba, South Florida, South & West Africa
L. hasselti	Australia, South and Southeast Asia, Africa, Philippines
L. histrix	Arabia
L. indistinctus	South Africa
L. kapito	New Zealand
L. mactans	United States, South Canada, Peru, Chile, Cuba, Mexico
L. menavodi	Madagascar
L. pallidus	Asia
L. tredcimyguttatus	North Africa, Southern Europe
BARTONELLOSIS (Verruga Peruana, Oroya fever, Carrion's Disease)	
Phlebotomus verrucarum	Peru, Ecuador, Southwest Colombia
CANTHARIASIS	
Coleoptera	Scattered

314

DISEASES AND IMPORTANT ARTHROPODS	KNOWN REGION OF INCIDENCE
DERMATOSES	
Anoplura (sucking lice)	Widespread
Arachnida (spiders, scorpions, mites & ticks)	Widespread
Collembola (springtails) Sharp bites followed by pruritus	Widespread
Diptera - Hemorrhagic punctures; pain, swelling, general discomfort	Widespread
Hemiptera	
Periodic blood suckers	Widespread
Siphonaptera (Fleas: human, dog, cat, chigoe, etc.)	Widespread
Marked dermatitis. Chigo (jigger), burrows in skin: may introduce tetanus, gas gangrene, etc.	
MYIASIS	
Specific and semi-specific	
CUTANEOUS	
Auchmeromyia luteola	Tropical Africa
Calliphora vicina	World-wide
C. vomitoria	World-wide
Callitroga hominivorax	Tropics and Subtropics of Western Hemisphere (Middle, Western & Southern United States)
Chrysomya bezziana	Oriental and Ethiopian regions
Cordylobia anthropophaga	Tropical Africa
Gasterophilus haemorrhoidalis	Western Hemisphere
G. intestinalis	Western Hemisphere
G. nasalis	Western Hemisphere
Hypoderma bovis	North Temperate Zone
H. lineatum	South from North Temperate Zone
Psorophora cyanescens	Mexico, Central & South America
P. ferox	Mexico, Central & South America
P. lutzi	Mexico, Central & South America
Sarcophaga haemorrhoidalis	Cosmopolitan
S. carnaria	Cosmopolitan
S. fuscicauda	Cosmopolitan
Wohlfahrtia magnifica	Mediterranean Region, Near & Middle East, USSR
W. meigenii	Western United States
W. vigil	Northern United States & Canada

DISEASES AND IMPORTANT ARTHROPODS	KNOWN REGION OF INCIDENCE
MYIASIS (cont.)	
ACCIDENTAL	
INTESTINAL	
Calliphora vicina	Cosmopolitan
C. vomitoria	Cosmopolitan
Chrysomya chloropyga	Africa, Australia, parts of Asia, various islands including the Philippines
C. putoria	Africa, Australia, parts of Asia
Drosophila spp.	Scattered
Fannia canicularis	Cosmopolitan
F. scalaris	Cosmopolitan
Helophilus sp.	Cosmopolitan
Hermetia illucens	Scattered
Megaselia scalaris	West Indies, N. America, Belgian Congo, India, Burma. Wide spread except Australian Region
M. rufipes	Australian Region
Musca crassirostris	India
Musca domestica	Cosmopolitan
Muscina stabulans	Cosmopolitan
Piophilia casei	Cosmopolitan
Rhyphus fenestralis	Scattered
Tubifera spp.	Cosmopolitan
GENITO-URINARY	
Calliphora spp.	Scattered
Fannia spp.	Scattered
Lucilia sp.	Scattered
Musca domestica	Scattered
Muscina spp.	Scattered
Piophila casei	Scattered
Psychoda sp.	Scattered
Sarcophaga canaria	Scattered
Sarcophaga sp.	Scattered
Sepsis sp.	Scattered
Syrphus sp.	Scattered
Tubifera sp.	Scattered

DISEASES AND IMPORTANT ARTHROPODS	KNOWN REGION OF INCIDENCE
MYIASIS (cont.)	
NASO-PHARYNGEAL-OPHTHALMOMYIA-SIS	
Hypoderma bovis	North Temperate zone
H. lineatum	South from North Temperate Zone
Oestrus ovis	U.S.S.R., North Africa, Palestine, United States, Western Europe
Rhinoestrus purpureus	U.S.S.R.
Chrysoma bezziana	Oriental & Ethiopian regions
Phaenicia sericata	China & North Africa
Wohlfahrtia magnifica	Mediterranean Region, Near & Middle East & U.S.S.R.
W. vigil	Northern U.S.A. and Canada
OPHTHALMIA NODOSA (Nodular conjunctivitis)	
Wind blown hairs of caterpillars	
Megalopyge opercularis	United States
PARALYSIS	
Tick	Widespread
PENTASTOMIASIS (Tongue worms)	
Pentastomes	India, Central & South America, Germany, Switzerland, Texas
SCHOLECIASIS	
Lepidoptera	Scattered
URTICATION	
Lepidoptera	Cosmopolitan
VENENATION	
Hymenoptera	Cosmoplitan
VESICATING & POISONOUS (Body fluids of blister beetles, gaseous irritation of Tribolium confusum to eyes and nose)	
Coleoptera	Cosmopolitan

SUMMARY OF THE MORE IMPORTANT INFECTIONS AND INFESTATIONS CAUSED BY ARTHROPODS

BACTERIA	HELMINTHS	PROTOZOA	RICKETTSIA	VIRUS	SPIROCHETES	MISCELLANEOUS
Cholera	Acanthocheilone- miasis	Amebiasis	Boutonneuse fever	Dengue	Relapsing fever	Arachnidism Necrotic Systemic
Conjunctivitis	Bancroft's filar- iasis	Balantidiasis	Bullis fever	Encephalitis: California	Endemic	Bartonello- sis
Dysentery	Bertielliasis	Chagas' disease	Maculatum disease	Equine: Eastern	Epidemic	Canthariasis
Food poisoning	Cysticercosis	Espundia	"Q" fever	Venezuelan	Tropical ulcer	Dermatoses
Paratyphoid	Diphylidiasis	Giardiasis	Rickettsial- pox	Western	Yaws	Myiasis Cutaneous,
Plague	Diphyllobothriasis	Kala-Azar	Spotted Fever	Japanese "B"		Eye, ear, nose, throat,
Tularemia	Dracontiasis	Malaria	Trench fever	Louping Ill		Genito- urinary,
Typhoid	Gnathostomiasis	Oriental sore	Typhus: Endemic	Russian Spring- Summer		Intestinal,
	Gongylonemiasis	Sleeping sick- ness	Epidemic	St. Louis		Ophthalmia- nodosa
	Hymenolepiasis		Scrub	West Nile		Paralysis, Tick
	Loiasis			Poliomeylitis		Pentastom- iasis
	Malayan filariasis			Rift Valley fever		Scholeciasis
	Mansonelliasis			Sandfly fever		Urtication
	Onchocerciasis			Trachoma		Venenation
	Sparganosis			Yellow fever		Vesication
	Trichuriasis					

318

KEY TO THE FAMILIES

ADULTS

1. Flagellum of antenna with 14 segments; subcostal vein
   ending above or before the base of the radial sector (vein 2);
   wings without scales. mouth parts short, unfit for piercing .... DIXIDAE
   Flagellum of antenna with 13 segments; subcostal vein ending
   much beyond the base of the radial sector (vein 2);
   wings with scales, at least on the wing fringe 2

2. Mouth parts short, unfit for piercing, palpi incurved; wing scales
   almost confined to the wing fringe .... CHAOBORIDAE
   Mouth parts modified to form a long, piercing proboscis,
   palpi not incurved; wing veins and legs scaly .... CULICIDAE

LARVAE

1. Thorax narrow with distinct segmentation; prolegs on the first
   two abdominal segments, tracheae ending in a pair of discs
   on the eighth abdominal segment .... DIXIDAE
   Thorax distinctly broader than abdomen, without distinct
   segmentation; paired prolegs lacking 2

2. Antennae prehensile, with long and strong apical spines .... CHAOBORIDAE
   Antennae not prehensile .... CULICIDAE

KEY TO THE SUBFAMILIES OF THE FAMILY CULICIDAE

ADULTS

1. Proboscis rigid, the outer half more slender and bent backwards;
   a spurious vein behind the fifth vein (a single genus,
   Toxorhynchites) .... TOXORHYNCHITINAE
   Proboscis more flexible, of uniform thickness (at times swollen
   at the tip), outer half not bent backwards; never a spurious
   vein behind the fifth vein 2

2. Abdomen without scales, or at least with the sternites largely bare;
   scutellum crescent-shaped, evenly setose; wings usually spotted:
   palpi of female usually as long as proboscis................... ANOPHELINAE
   Abdomen with both tergites and sternites completely clothed with scales;
   scutellum trilobed, the setae only on the lobes; wings not spotted;
   palpi of female much shorter than proboscis .... CULICINAE

LARVAE

1. Without a siphon .... ANOPHELINAE
   With a siphon (which is as long as it is broad or longer) 2

2. Mouth brushes with a few (10) stout rakers; usually pink
   coloration (a single genus (Toxorhynchitinae) .... TOXORHYNCHITINAE
   Mouth brushes with many hairs (30 or more); pink
   coloration only found in one unimportant genus .... CULICINAE

KEY TO THE OLD WORLD GENERA OF THE SUBFAMILY CULICINAE

ADULTS

1. Squama fringed (fringe usually complete, rarely interrupted);
   sixth longitudinal vein reaching well beyond the base of the
   fork of the fifth longitudinal vein 2

2. Pulvilli present pleural chaetotasxy well developed, but spiracular
   and postspiracular bristles absent .... Culex
   Pulvilli absent or rudimentary 3

3. Postspiracular bristles absent; claws of female simple (except
   in Leicesteria and Heizmannia) 4
   Postspiracular bristles present, even if only one or two; claws of
   female usually toothed; dorsocentaal and upper sternopleural
   bristles nearly always well developed 11

4. Spiracular bristles present (sometimes only one or two) 5
   Spiracular bristles absent 6

5. Several upper sternopleural bristles; main stem vein at base
   of wing usually hairy on underside .... Culiseta
   At most, one or two sternopleural bristles; main stem vein
   bare on underside (Oriental, Australasian, and one
   Japanese species) .... Tripteroides

6. Dorsocentral (on the mesonotum) and prescutellar bristles
   absent; pronotal lobes approximate (Oriental and
   Australasian) .... Heizmannia
   Dorsocentral and prescutellar bristles well developed;
   pronotal lobes well separated   7

7. Postspiracular area scaly; claws of female usually toothed; palpi
   of female more than half as long as the proboscis (Oriental
   only) .... Armigeres (subgenus Leicesteria)
   Postspiracular area bare; claws of female simple 8

8. All segments of antenna of female, and last two of antenna
   of male short and thick; middle femora with scale–tuft
   (none Palearctic) .... Aedomyia
   Antennae normal, slender; middle femora without scale–tuft 9

9. First segment of front tarsi longer than the last four together;
   fourth very short in both sexes (none Australian) .... Orthopodomyia
   First segment of front tarsi not longer than last four together;
   fourth not shortened in the female 10

10. Proboscis of male much swollen apically, of female slightly
    or else fork of second longitudinal vein shorter than stem
    of the fork (none Palearctic) .... Ficalbia
    Proboscis not swollen apically; fork of second longitudinal
    vein at least as long as the stem .... Mansonia (in part)

11. Head with numerous short hairs on vertex in addition to the
    orbital row; antennae thick in both sexes, not plumose in
    male (one species from New Zealand only, Opifex fuscus) .... Opifex
    Head without hairs on vertex apart from the orbital row;
    antennae slender in female, nearly always plumose in male 12

12. Eyes widely separated, space between them clothed with metallic
    silvery scales (Ethiopian only) .... Eretmapodites
    Eyes less widely separated (sometimes touching), space between
    them not clothed with metallic silvery scales   13

13. Wing scales generally mostly narrow (when, rarely, all are broad,
    the claws of the female are toothed); usually a few hairs on the
    upper surface of the stem vein at base of wing.......................... 14
    Wing scales all very broad; claws of female simple; stem vein
    bare ....Mansonia (in part)

14. Proboscis more slender, not recurved at tip in repose in
    the living insect; ornamentation various .... Aedes
    Proboscis rather stout, recurved at tip in repose in the
    living insect; dark species with flat scales on vertex
    and scutellum (Oriental and Australian only) .... Armigeres

15. Wing membrane without microtrichia (minute hairs) (or these
    only visible under a high magnification); fork of second
    longitudinal vein shorter than the stem of the fork.................. **Uranotaenia**
  Wing membrane with distinct microtrichia (visible under
    a magnification of 50x)   **16**

16. Spiracular bristles absent; clypeus normal 17
  Spiracular bristles present (one or more); clypeus rather
    small and narrow; fork of the second longitudinal vein
    longer than the stem of the fork 18

17. Fork of second longitudinal vein shorter than the stem of the
    fork; several posterior pronotal bristles; wing scales normal
    (one species from Malaya and Borneo only, _Zeugnomyia_ gracilis)....**Zeugnomyia**
  Fork of second longitudinal vein longer than the stem of
    the fork; two posterior pronotal bristles; wing scales
    emarginate at tips (none Palearctic) .... **Hodgesia**

18. Proboscis very hairy, much enlarge at tip (Ethiopian and
    Oriental only)... **Malaya**
  Proboscis not hairy, rarely enlarged at tip (Oriental only)............. **Topomyia**

LARVAE

1. Anal segment with ventral brush of at least four separate hairs 2
  Anal segment with one pair of ventral hairs 17
  Anal segment without ventral hairs (West African sub-region,
    a single species, <u>Culex</u> <u>moucheti</u>) .... **Culex** (in part)

2. Eighth segment with lateral sclerotized plate, with one row
    of comb teeth on its margin (plate sometimes weak);
    mouth brushes normal 3
  Eighth segment without lateral plate 4

3. Siphonal pecten present; antennae short .... **Uranotaenia**
  Siphonal pecten absent; antennae large and flattened (none
    Palearctic) .... **Aedomyia**

4. Siphon with pecten, the teeth of which are nearly always denticulate
    (pecten rarely reduced) 5
  Siphon without pecten, or rarely with a few simple teeth 10

5. Siphon with several pairs of hair tufts or else very long
    and slender... 6
  Siphon with one pair of hair tufts and never very long 7

6. Mouth brushes forming matted prehensile tufts (none
      Palearctic) .... Culex (subgenus Lutzia)
   Mouth brushes normal .... Culex and Culiseta
                                                    (subgenera Culicella and Climacura)

7. Siphonal hair tuft basal in position .... Culiseta
   Siphonal hair tuft near middle, often beyond 8

8. Mouth brushes forming matted prehensile tufts
      (not Palearctic) .... Aedes (subgenus Mucidus)
   Mouth brushes normal 9

9. Anal segment with complete sclerotized ring (Java, a single
      species, Uranotaenia ascidiicola) .... Uranotaenia (in part)
   Anal segment (except rarely) with dorsal sclerotized saddle.. Aedes and Heizmannia

10. Antennae short, with small simple shaft hair; metapleural
      plate small 11
   Antennae longer, with branched hair on shaft; metapleural
      plate large 14

11. Metapleural hairs all short and inconspicuous (a single species
      from New Zealand, Opifex fuscus) .... Opifex
   Three metapleural hairs long (normal) 13

12. Siphonal hair tuft large, as in Aedes, etc. 12
   Siphonal hair small and simple (a single species from Malaya
      and Borneo, Zeugnomyia gracilis) .... Zeugnomyia

13. From Oriental and Australasian regions .... Armigeres
   From Ethiopian region .... Eretmapodites

14. Siphonal valves highly modified for piercing stems of aquatic plants ...... Mansonia
   Siphonal valves not specially modified 15

15. Abdominal segments VI-VIII normally with dorsal sclerotized
      plates (none Australian) .... Orthopodomyia
   Abdomen without plates on segments VI-VIII 16

16. Antennal tuft well removed from tip (none Palearctic) .... Ficalbia
   Antennal tuft close to tip (none Palearctic) .... Hodgesia

17. Maxillae large, ending in two strong articulated horns
      (Papua and Northern Australia only) .... Tripteroides (subgenus Rachisoura)
   Maxillae large, produced into a long non-articulated horn
      (Malaya, Borneo and Sumatra, a single species,
      Topomyia argenteoventralis) .... Topomyia (in part)
   Maxillae unmodified 18

323

18. Ventral hair of anal segment single, abdomen without stellate
hairs (Ethiopian and Oriental only); metathorax without
long spine .... Malaya
Ventral hair of anal segment branched 19

19. Metathorax with long spine dorsolaterally; abdomen always with
stellate hairs, which are often very numerous (Oriental and
Australasian with one Japanese species only) .... Tripteroides

Metathorax without long spine; stellate hairs of abdomen few or
absent (Oriental only) .... Topomyia

KEY TO THE NEW WORLD GENERA OF THE SUBFAMILY CULICINAE

ADULTS

1. Anal vein (vein 6) extending well beyond fork of cubitus (vein 5);
wings with microtrichia 2
Anal vein ending opposite or basad of cubital fork; wings without
microtrichia .... Uranotaenia

2. Prescutellar setae and postspiracular setae absent .... Haemagogus
Prescutellar setae present 3

3. Postspiracular setae present 4
Postspiracular setae absent 6

4. Spiracular setae absent 5
Spiracular setae present, sometimes small .... Psorophora

5. Wing scales mostly narrow, or when broad, setae are present on
upper side of the base of the first vein .... Aedes
Wing scales broad, setae absent on upper side of base of first
vein .... Mansonia (subgenera Mansonia and Rhynchotaenia)

6. Lower side of base of first vein distinctly pilose; spiracular
setae present .... Culiseta
Lower side of base of first vein scaly or bare; spiracular setae
absent 7

7. No setae on upper side of base of first vein; wing scales broad 8
Setae present in this area; wing scales narrow 10

324

8. No mid mesepimeral setae; fourth tarsal joint of fore tarsus at
   least as broad as long .... Orthopodomyia
   Mid mesepimeral setae present; fourth fore tarsal joint not
   shortened 9

9. Post marginal wing scales longer than width of anal cell; antennal
   joints but little longer than broad .... Aedomyia
   Post marginal wing scales shorter than width of anal cell; antennal
   joints much longer than broad .... Mansonia (subgenus Coquillettidia)

10. Mid mesepimeral setae numerous .... Culex (subgenus Lutzia)
    These setae absent or few, about three at most   11

11. Antennae much longer than length of proboscis .... Deinocerites
    Antennae not longer than proboscis .... Culex

LARVAE

1. Head of fourth stage larvae elongate elliptical .... Uranotaenia
   Head rounded or transverse, not elongate 2

2. Air tube or siphon without pecten 3
   Air tube with pecten 5

3. Air tube truncated, with a saw-toothed projection for piercing
   plant tissue .... Mansonia
   Air tube not so modified 4

4. Antennae small .... Orthopodomyia
   Antennae inflated .... Aedomyia

5. A single paired hair tuft on air tube (rarely with additional hairs) 6
   Air tube with several tufts (if obsolete, the tube is much elongated) 8

6. Head with lateral pouches, covering projections of the maxillae ..... Deinocerites
   Without this structure 7

7. Mouth brushes prehensile, or air tube or antennae much
   inflated .... Psorophora
   Without these peculiar modifications .... Aedes and Haemogogus

8. Mouth brushes prehensile .... Culex (subgenus Lutzia)
   Mouth brushes normal, ciliform .... Culex

325

Pest Control Responsibilities
of Medical and Public Works or Marine Corps Maintenance Officers

1. <u>Purpose</u>. This enclosure contains detailed instructions and procedures for the coordination of medical and public works type responsibilities and the accomplishment of pest control operations in accordance with basic policy established by SECNAV INST 5420.17 (enclosure (1)).

2. <u>Background.</u> Surveys by trained personnel have repeatedly revealed disease potentials, extensive material losses, or incipient infestations not detectable by routine inspection parties. Subsistence and structural losses are often accepted as inevitable without realization that they are usually preventable. Outbreaks of vector-borne diseases have occurred when troops have entered infested areas without knowledge of available preventive measures. In other instances, technical surveys have resulted in elimination of expensive control operations which were found to be unnecessary, or in the substitution of less costly measures. Efficient and safe preventive and control measures against pests require expert technical guidance and trained personel, particularly since the introduction of new problems such as highly toxic and concentrated pesticides, varied types of dispersal methods, and the development of resistance to chemicals by many pests.

3. <u>Areas of Technical Responsibility</u>.

    a. <u>Vector Control</u>. Primary responsibility for recommendations to the commanding officer to effect vector (health) control is assigned to the medical department. The term vector is used in the broad sense to include all pests of public health or sanitary importance, such as mosquitoes, biting flies, filth flies, lice, fleas, mites, ticks, rodents, and other hosts of pathogenic organisms and parasites.

    b. <u>Economic Pest Control</u>. All other pests, hereafter referred to as economic pests, are normally controlled by the public works department or Marine Corps maintenance department as delegated by the commanding officer. Included in this category are termites and other wood-destroying insects, moths, subsistence pests, landscape pests, marine borers, roaches, and ants.

4. <u>Availability of Military (BUMED) and Civilian (BUDOCKS) Entomologists at District and Other Senior Command Levels</u>.

    a. <u>In certain naval districts</u>, civilian positions, Special Assistant for Pest Control (DD-111), under the assistant district public works officer for maintenance and operations have been activated (enclosure (3)). These positions should be activated in other naval districts when required (reference (b)).

b. <u>Outside naval districts,</u> Director, BUDOCKS Overseas Division, should take the necessary steps to establish comparable public works billets when economic pest problems so justify.

c. <u>Throughout the Naval Establishment</u>, a limited number of military entomologists of the Medical Service Corps (NOBC - 0827), are available for utilization by those commands in which significant vector problems exist (enclosure (3)). Orders and authority should be provided, by the proper echelon of command (either through established billets or on an additional duty basis), to insure that services of these military entomologists are utilized on the broadest command basis possible.

d. <u>Policy for Assignment and Cross-Utilization.</u> Where vector and economic pest activity is extensive, entomologists in each category may be required. However, where only one is present, his services will be utilized for both economic and vector pest problems as necessary.

5. <u>Medical Department Functions at Activity Level.</u>

a. <u>General Responsibilities for Vector (health) Surveillance.</u> The medical officer and his technical assistants (enclosure (3)) will be responsible to the commanding officer for the following at all Naval and Marine Corps Commands:

(1) Inspections and surveys to determine and identify the species, source, location, and density of vectors.

(2) Recommendation of sanitary standards and procedures which affect the presence of vectors, recommendation of vector control methods, and evaluation of the effectiveness of control measures.

(3) Inspection and instructions to assure that toxic pesticides are used safely in accordance with pertinent regulations and that control operations are planned and supervised by qualified personnel.

(4) All personal measures for protection against disease vectors.

(5) Coordination with civilian and other governmental agencies having vector control problems that may affect naval personnel on or in the vicinity of a station.

b. <u>Supervision of Vector Control Operations.</u>

(1) Operating Forces (including assigned shore activities), Outside Naval Districts. Supervision will be accomplished at shore based facilities by Disease Vector Control Officers (NOBC - 0882), or by Environmental Sanitation Technicians (ENJC - 8432) with special training in vector control. The technical guidance of a medical entomologist (NOBC - 0827), will be provided as required.

(2) <u>Naval Shore Establishment</u>. When vector control services are performed by the public works department, that department will provide supervision by qualified pest control personnel, with the following exceptions:

(a) Medical department technicians will supervise vector control operations, with the technical guidance of a medical entomologist, at activities designated by the Bureau of Medicine and Surgery for on-the-job training of vector control personnel.

(b) Temporary utilization of medical department technicians for supervision in emergencies of vector-borne disease outbreaks or in other special circumstances may be authorized by District Commandants or other appropriate commands.

c. <u>Special Operating Units</u>. Preventive medicine units, when authorized by proper authority, may conduct vector control operations for the purpose of training personnel, field testing of new methods and equipment or providing area-wide services which involve specialized equipment. In the Navy advanced base organization (ABIOL (abridged) NAVSANDA Pub. No. 28) trained supervisory personnel and materials are provided by appropriate advanced base functional components.

6. <u>Public Works Department or Marine Corps Maintenance Department Functions at Activity Level</u>.

a. Control of economic pests and operational support of vector control programs are the responsibilities of the Commanding Officer. Normally, these functions are delegated to the public works or Marine Corps maintenance officer. The program should be implemented in the following manner:

(1) Provision of trained qualified personnel to guide and accomplish pest control operations.

(2) Inspections and surveys of pest control problems to establish preventive control programs.

(3) Periodical training and education of supervisory personnel in order that the pest control program may be kept current with new control techniques and chemical developments.

(4) Coordination with community pest control activities of other civilian or governmental agencies as outlined by reference (d).

b. <u>Technical Supervision</u>. Public works officers or Marine Corps maintenance officers may obtain the technical assistance of the DD-111, Special Assistant for Pest Control, District Public Works Office, or Office of Director, BUDOCKS Overseas Division, in selecting and training capable supervisors and operators. Properly

trained and qualified pest control personnel assure the public works officer or the
Marine Corps maintenance officer of the safest, most effective and economical pro-
gram. As supervisors and operators demonstrate on-the-job competence in planning
operations and in selecting, formulating, and applying toxic chemicals correctly,
recognition of this competence may be made by the awarding of appropriate certifi-
cates to supervisors and operators as recommended by the DD-111 and approved by
the public works officers. Periodic district-wide training conferences conducted
jointly by medical and public works departments, during which final qualification
tests may be given, present an effective method of initiating certification procedures.
Certificates should be recorded and renewed periodically or surrendered at termina-
tion of employment as a Navy Civilian Pest Control Supervisor or Operator.

c. Fiscal Procedure. Provisions will be made for vector and economic pest con-
trol services for the various management control activities at naval bases, stations,
or similar installations as requested. Such services will be requested in the manner
outlined in Section VIII, Chapter 5, Vol. 3, NavCompt Manual, citing the appropria-
tion and allotment chargeable. When requesting these services, cost estimates should
be obtained and allotment obligations established as indicated. The services of the
District Public Works Office (DD-111), may be utilized by budgeting activities to assist
in determining funds necessary for pest control requirements. At multiple-sponsored
activities cross-financial support of the public works pest control program should be
encouraged and initiated at the earliest possible date, in order to provide adequate
materials, equipment, and personnel in the most economical and effective manner
possible. In those areas where preventive medicine units conduct specialized area-
wide operations, the procedures of paragraph 5c will be followed.

7. Pest Control Aboard Ships and Stations Without Public Works or Marine Corps
Maintenance Departments.

a. Both Vector and Economic Pest Control. This work will normally be accom-
plished by the ship or station personnel with general-use items, as provided in para-
graphs 5 and 6 of reference (c), under the technical supervision of the senior medical
department representative.

b. If Adequate Control is not Effected. The advice of specialists (enclosure (3))
should be obtained from the nearest activity having personnel qualified to advise.
Where special services are necessary and are of such nature as to require reimburse-
ment, payment should be made in accordance with paragraph 6c.

8. Fumigation of Ships. Fumigation of ships is indicated normally only when required
for rodent control by quarantine officials of the U. S. Public Health Service and is then
accomplished by special operators of that service in accordance with BUSANDA Man-
ual, par. 81298.8.